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THE USE OF CONSTANT AND VARIABLE SPEED MOTORS FOR DRIVING WATER AND SEWAGE PUMPS[1]

BY L. F. ADAMS[2]

Recent advance in the design and application of motors for use with pumps merits the attention of all connected with water and sewerage systems. I assume that all of you are familiar with the direct current constant and varying or adjustable speed motors for driving reciprocating and centrifugal pumps. Also you are no doubt acquainted with the common squirrel cage induction motor for constant speed drive and the slip ring induction motor for either constant or varying speed drive. However, it is doubtful if many realize the possibilities of the synchronous motor for constant speed drive or know anything about the brush shifting polyphase motor for varying speed drive. These types of motors offer advantages that should receive your consideration.

While the induction motor has been and still is a very satisfactory motor for pump drive, it has one bad feature, that is, low power factor. This means extra losses incurred by transmitting the excitation to the load and extra investment in larger generators, transformers, and power lines to carry the excitation. Many of the power supply companies are now insisting that the power factor must be a certain amount and the power bill is increased if the power factor

[1] Presented before the Detroit Convention, May 22, 1923.

[2] Power and Mining Engineering Department, General Electric Company, Schenectady, N. Y.

falls below this fixed value, while on the other hand a bonus in some cases is given if the power factor is higher. One of the large companies furnishing power has a clause in its contract as follows:

> The rates set forth in the preceding tariff are based upon the maintenance by the consumer of an average power factor of 85 per cent for each month, as shown by integrating instruments. When the average monthly power factor is above or below 85 per cent, the kilowatt hours as metered, will, for billing purposes, be multiplied by the following constants.

Instead of giving a tabulation of constants I will interpret them with an example. If the power factor is 0.5 the number of kilowatts billed will be about one-third larger than those actually metered, whereas if the power factor is unity, the number of kilowatts billed will be 5 per cent less than those actually metered. Under such contracts it is important to keep the power factor as high as possible. The same conditions exist and the same recommendations apply to those plants that generate their own power instead of buying it.

The power factor could be corrected by various means, but, wherever possible, it is better to avoid poor power factor by the use of synchronous motors.

Without going into details it is sufficient to say that the development through which the self-starting synchronous motor has passed during recent years has made this type of machine admirably suitable for constant speed pump drives. Especially is this true for the centrifugal pump, that is usually started with the discharge valve closed requiring usually not over 30 per cent starting torque and 50 to 60 per cent pull in torque. Motors for this service are designed to develop a starting torque of 50 per cent of full load torque with the 70 per cent compensator tap and pull in torque of 50 per cent on the 70 per cent compensator tap. Greater pull in torque will be obtained if full voltage is applied to the motor with the field switch open.

In some applications it is desirable to start with the discharge valve open thereby requiring approximately full load pull in torque. In the past a magnetic clutch, which is expensive and requires considerable space, has often been placed between the synchronous motor and the pump, and this made it possible to start the motor without load and then accelerate the pump by means of the clutch. However, synchronous motors are now built with adequate pull in torque and with such the magnetic clutch is no longer necessary.

Synchronous motors are also used for direct connection to reciprocating pumps. It is usually possible to place sufficient weight in

the rotor of the synchronous unit so that no extra fly wheel is necessary. For such pumps full sized by-passes must be furnished in order to reduce the starting torque to a reasonable value.

The synchronous motor may be started either by hand or by remote or automatic control. The motor may be designed for unity power factor or it may be made larger in order to give additional power factor correction thereby compensating for low power factor caused by induction motors in the station. Naturally the more correction desired the larger the motor and the greater the loss.

Because the induction motor could give very high starting torque it has been necessary to use it wherever the synchronous motor, because of its better power factor, would have been chosen if a high torque synchronous motor were available. A synchronous motor of special mechanical construction, which gives it a starting torque far in excess of any heretofore attained, is now available and is particularly fitted for centrifugal and reciprocating pumps with discharge valve open or by-pass omitted, for air compressor, omitting unloading valves, vacuum pumps, etc.

The electrical construction and essential dimensions of this motor are identical with the standard synchronous motor of the same rating. The special mechanical features (fig. 1) include the suspension of the armature (stator) so that it can rotate during the starting period. Hollow journal extensions on the end shields are carried by bearings at the inner ends of the standards which carry the motor shaft. The periphery of the frame is machined for a braking surface and is fitted with the standard brake band, lever and quadrant of mine hoist and cable way practice. The current is taken to the armature winding through rings which are normally stationary.

When starting with load, the brake is released, the armature is energized and comes up to induction motor speed. The field (rotor) is then energized and the armature comes to synchronous speed. Now by applying the brake the armature can be slowed down which results in the starting and speeding up of the field and attached load. The acceleration proceeds to synchronism proportionally as the armature is brought to rest. The brake is locked and the unit has become a normal synchronous motor.

Throughout the acceleration of the field from zero to synchronism the motor is able to apply torque to the connected load several times greater than its normal full load torque.

The current drawn during starting bears the same relation to the full load current as the starting torque required bears to the full load torque. That is, a starting torque of 125 per cent full load torque will draw 125 per cent of full load current from the line.

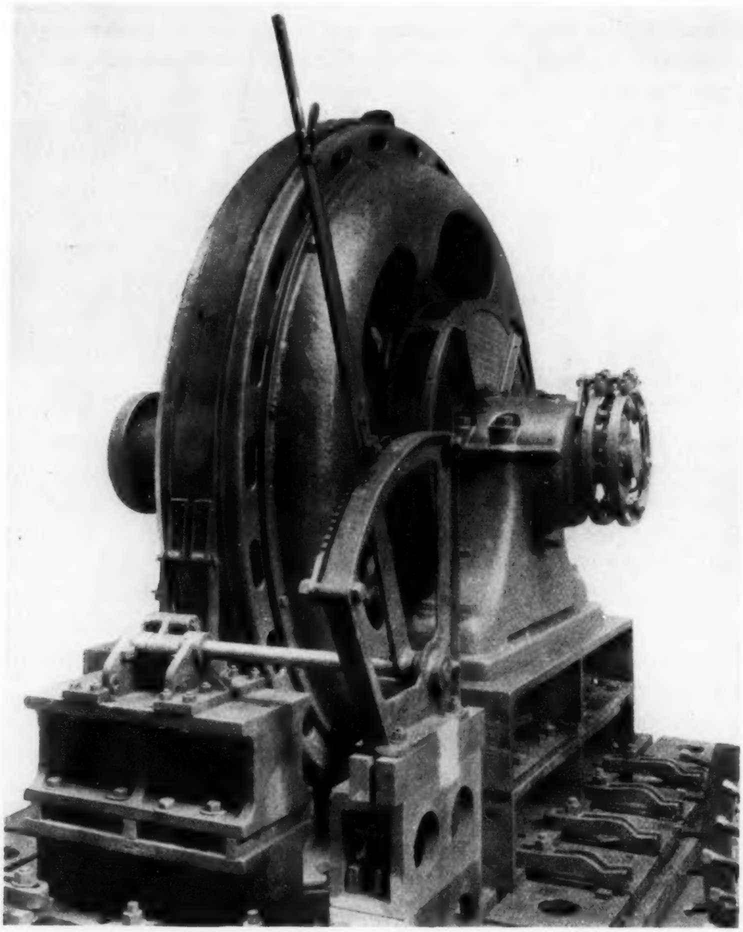


FIG. 1. A SUPER SYNCHRONOUS MOTOR RATED 450 H.P. AT 187.5 R.P.M. TO DRIVE A 7-FOOT BY 22-FOOT BALL-PEB MILL (CEMENT INDUSTRY) THROUGH A SINGLE-GEAR REDUCTION

Heretofore when synchronous motors have been connected to loads that could not be relieved during starting, it has been necessary to interpose two extra bearings and a clutch of some sort that would allow the motor to come up to synchronous speed while disconnected.

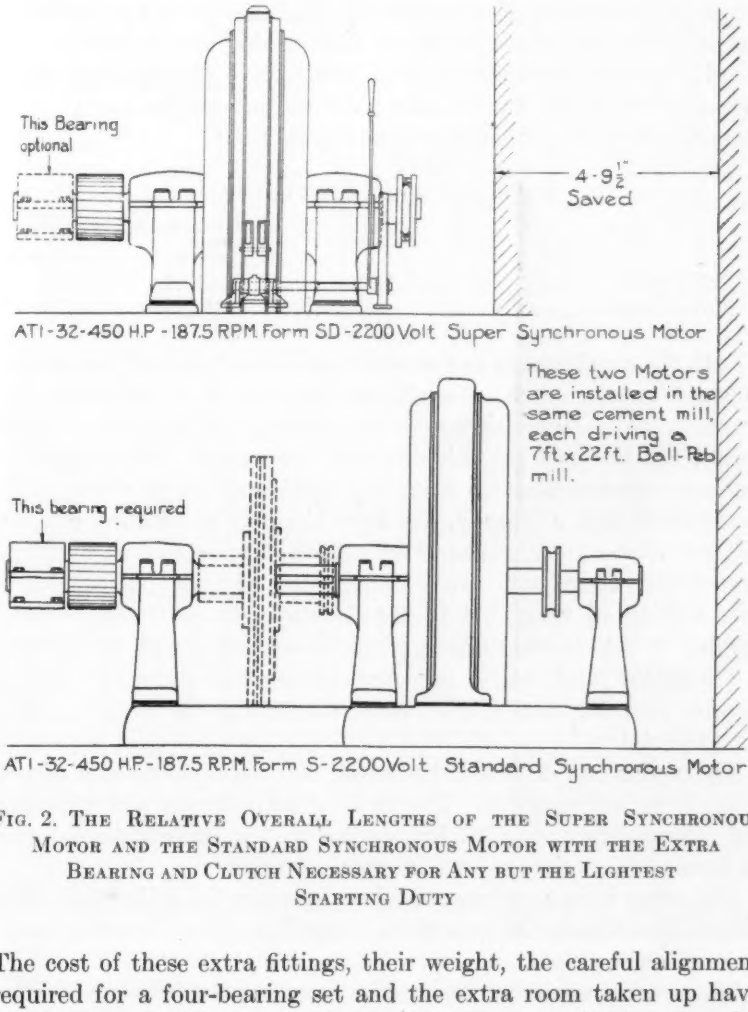


FIG. 2. THE RELATIVE OVERALL LENGTHS OF THE SUPER SYNCHRONOUS MOTOR AND THE STANDARD SYNCHRONOUS MOTOR WITH THE EXTRA BEARING AND CLUTCH NECESSARY FOR ANY BUT THE LIGHTEST STARTING DUTY

The cost of these extra fittings, their weight, the careful alignment required for a four-bearing set and the extra room taken up have been serious handicaps working against the use of this otherwise very desirable type of motor (fig. 2).

The designer being freed from the consideration of starting torque can accentuate the other desirable motor characteristics and can secure the desired rating in smaller dimensions.

There is a progressive practice in electric drives tending to reduce motor speeds in order to do away with part or all of the speed reducing devices heretofore employed. This tendency toward lower speeds makes induction motors less and less desirable because of the greatly reduced power-factor and efficiency. The efficiency and power-factor of the supersynchronous motor compares with like characteristics of an induction motor as follows:

Rating 450 h.p., 187.5 r.p.m., 2200 v.

	Super synchronous motor per cent	*Induction motor per cent*
Efficiency	93.5	89.9
Power factor	Unity	70.0

Both the synchronous and supersynchronous types of motors are constant speed motors. Sometimes, however, it is desirable and necessary to use varying speed pumps requiring a varying speed motor. In the past the slip ring induction motor, with secondary resistance control through a limited number of steps, resulting in considerable loss of energy, has been the only alternating current motor available. The demand for a motor having speed regulation over a wide range with small increments and with good efficiency over this speed range led to the development of the adjustable varying speed, brush shifting, singlephase and polyphase motors.

The motor consists of a stationary member or stator, a rotating member or rotor, and a transformer connecting the rotor in series with the stator.

The stator has distributed winding and is similar to that of the ordinary induction motor. The stator of an induction motor having the same number of poles, horsepower, voltage and frequency can be used without change for numerous ratings.

The rotor is in appearance and design essentially like that of a direct-current motor or generator, except that the armature voltage is considerably lower.

The rotor transformer is simply a series transformer with the primary in series with the stator of the motor and the secondary connected to the rotor through the brushes and commutator. This transformer not only supplies a lower commutator voltage, but, by its

ability to become saturated, limits the no load speed of the motor to a safe value. This limit is approximately 150 per cent speed.

The change in speed is obtained by shifting the brushes. In a certain brush position the fluxes from the stator and rotor so com-

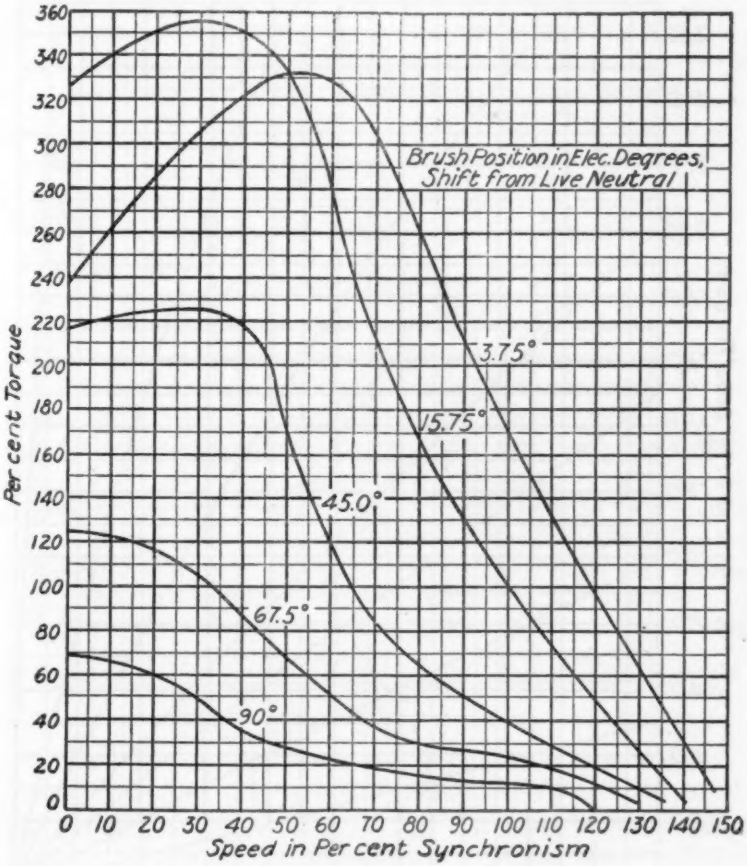


FIG. 3. TYPICAL SPEED-TORQUE CURVES OF THE BRUSH-SHIFTING MOTOR FOR VARIOUS POSITIONS OF THE BRUSHES

bine that no torque is produced. Shifting the brush position slightly results in a torque-producing flux, which causes rotation. As the shift is increased the resulting torque producing flux continues to enlarge and the speed becomes higher.

The maximum capacity for which these motors can be built is limited by commutating conditions. It has been found by experience that a limit of 30 h.p. per pole for 60-cycle motors and 70 h.p. per

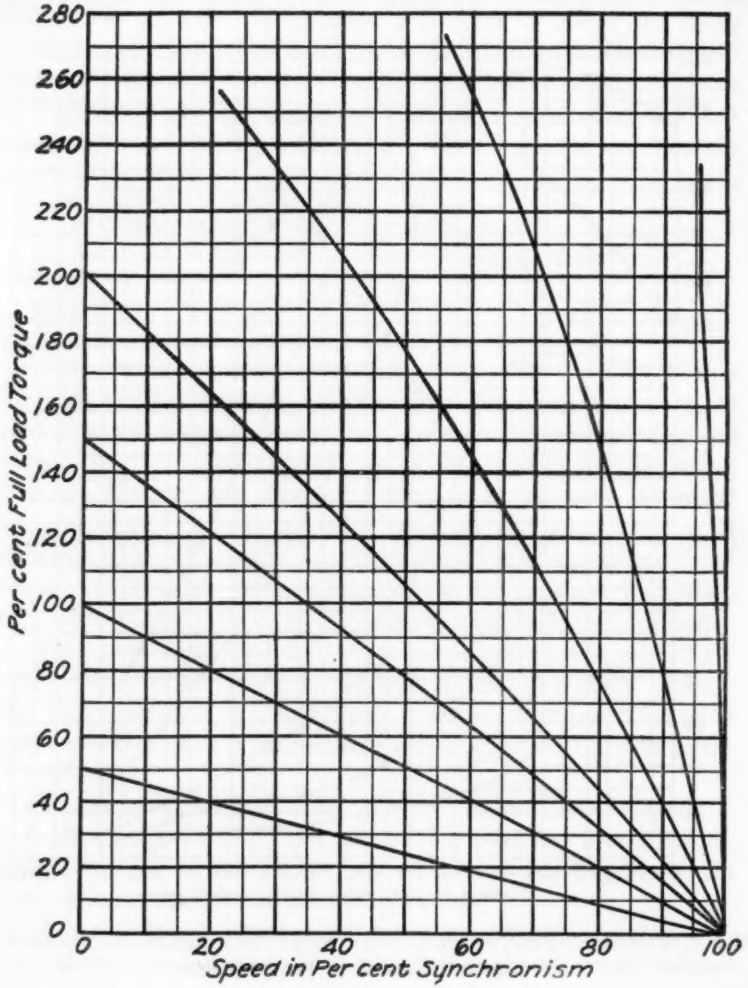


FIG. 4. SLIP RING MOTOR SPEED-TORQUE CURVES WITH VARIOUS AMOUNTS OF RESISTANCE IN THE MOTOR CIRCUIT

pole for 25-cycle motors may be used for rough approximations. This rule of thumb gives a limit of about 175 h.p. for 1200 r.p.m. motors and 350 h.p. for 600 r.p.m. motors.

The speed torque curves of figure 3 show that the characteristics of this motor compare favorably with those of slip ring induction motors having secondary resistance control (fig. 4). Wherever a slip ring induction motor is applicable for adjustable varying speed service the brush shifting motor may be applied, and in addition to

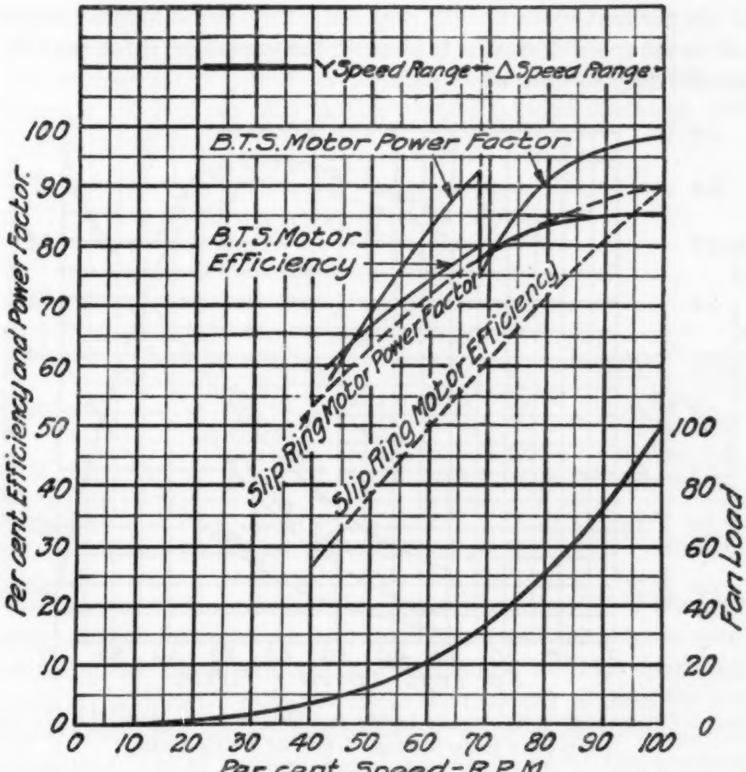


FIG. 5. TYPICAL COMPARATIVE EFFICIENCY AND POWER FACTOR CURVES OF BTS AND SLIP RING MOTORS UNDER FAN LOAD

having similar series characteristics it provides an infinite number of speed points. For centrifugal pumps, fans, etc., where the torque decreases rapidly with the speed, stable conditions exist at all speeds practically down to standstill.

Typical comparative efficiency and power factor curves for the brush shifting and slip ring motors when driving a fan load or similar

loads such as pumps are given in figure 5. One hundred per cent speed for the brush shifting motor is equal to 12.5 per cent above synchronism, while for the induction motor it equals full load speed, which is approximately 96 per cent of synchronism. This comparison assumes that the motors are driving equal loads, but that the machine for the slip ring motor is designed for a slightly lower speed. At 100 per cent speed the slip ring motor efficiency is slightly higher, but as the speed decreases the loss in the secondary resistors causes the efficiency to drop off rapidly.

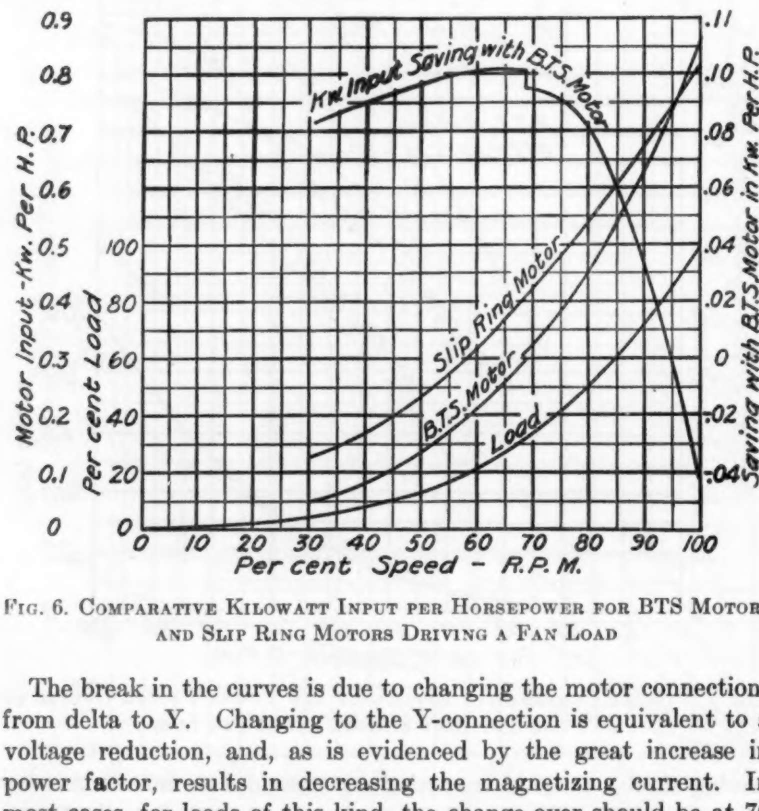


FIG. 6. COMPARATIVE KILOWATT INPUT PER HORSEPOWER FOR BTS MOTORS AND SLIP RING MOTORS DRIVING A FAN LOAD

The break in the curves is due to changing the motor connections from delta to Y. Changing to the Y-connection is equivalent to a voltage reduction, and, as is evidenced by the great increase in power factor, results in decreasing the magnetizing current. In most cases, for loads of this kind, the change-over should be at 70 per cent speed. When this change is made a different speed is obtained for the same brush setting.

The benefit of this higher efficiency is more clearly shown by figure 6 which gives the comparative kilowatt input per horsepower when

operating at different speeds. The saving in kilowatt input per horsepower, by using the brush shifting motor instead of the slip ring induction motor, is also shown. If the motors in question are 100 h.p., the kilowatt saving at 75 per cent speed will equal 100×0.091, or 9.1 kilowatts (fig. 6). The saving per year at this speed, assuming 365 twenty-four hour days (8760 hours), will be 79,700 kilowatt-hours.

By estimating in detail the operating speed cycle that is required a more representative power saving may be calculated as follows: Assume a 100 h.p. fan unit having a speed cycle of operation each day equivalent to:

4 hours run at 100 per cent speed
8 hours run at 85 per cent speed
8 hours run at 65 per cent speed
4 hours run at 50 per cent speed

From figure 6

HOURS	PER CENT SPEED		KILOWATT-HOURS
4	−100	$= 4 \times 100 \times 0.045 =$	18.0 loss
8	−85	$= 8 \times 100 \times 0.058 =$	46.4 saving
8	−65	$= 8 \times 100 \times 0.102 =$	81.6 saving
4	−50	$= 4 \times 100 \times 0.095 =$	38.0 saving

Total kilowatt hours saved per day 148
Total kilowatt hours saved per year (365 days) 54000

At 1 cent per kilowatt-hour this equals a saving of $540 per year, which, capitalized at 15 per cent for interest and depreciation, etc., justifies an additional expenditure of $3600 for the BTS equipment. This is a conservative estimate, for in the majority of cases the cost of power exceeds 1 cent per kilowatt-hour; but even so, the additional expenditure that is justified would practically cover the complete charge for a new motor and therefore warrant the use of the brush shifting equipment even though the slip ring motor could be obtained for nothing.

The importance of this increased efficiency for varying speed, fan drive, or similar drives is further illustrated by figure 7, where the operating cost per horsepower per year is plotted against speed. This operating cost includes interest on the capital investment and depreciation at 15 per cent, and a power charge of one cent per kilowatt-hour input. This shows that, above 91.5 per cent speed,

the BTS motor is generally the more expensive, but for operation at any speed below this it is by far the cheaper equipment. Assume for example a 100-h.p. motor operating continuously at 70 per cent speed: The operating cost per horsepower per year for the slip ring motor is \$39.60 and for the BTS motor \$33.50. Therefore, with a

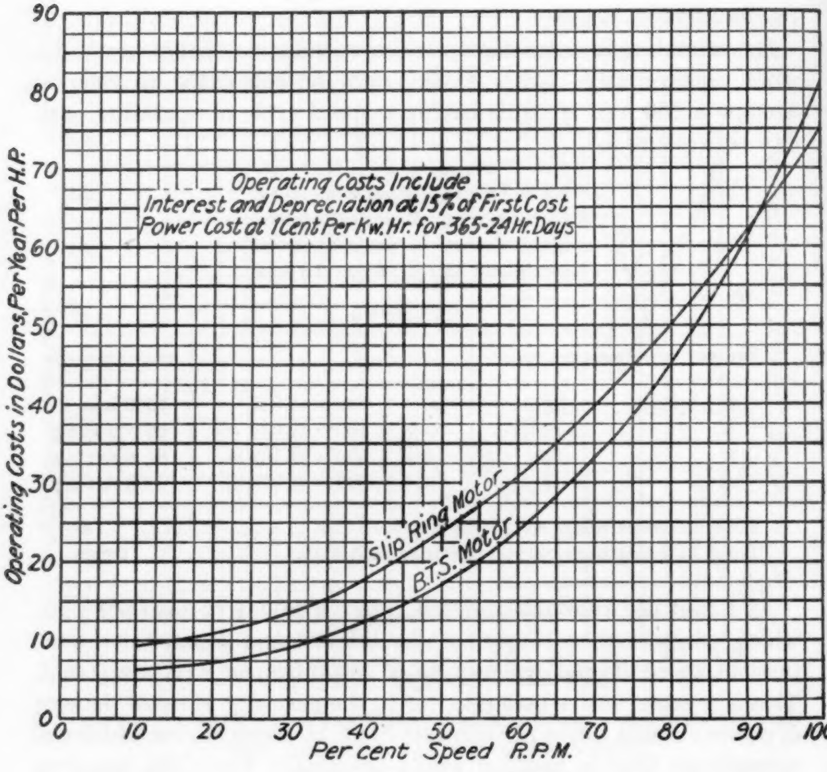


FIG. 7. COMPARATIVE OPERATING COSTS FOR BTS MOTORS AND SLIP RING MOTORS AS AFFECTED BY THE OPERATING SPEED

100-h.p. motor there would be a saving of \$610 per year and at the end of six years the BTS motor would have paid for itself.

For loads requiring constant torque throughout the entire speed range the BTS motor is even more desirable, as is shown by the curves of figures 8 and 9. At 70 per cent speed (fig. 9) the saving is 0.2 kilowatt per horsepower as compared with 0.092 kilowatt per

horsepower with a fan load (fig. 6). It will be noted that with a slip ring motor driving a constant torque load the input remains constant for all speeds, while the horsepower output decreases directly with the speed.

This type of motor was used for three of the vertical centrifugal pumps in the sewage disposal plant at Albany, New York. The pumps have a capacity of pumping from a rated minimum of

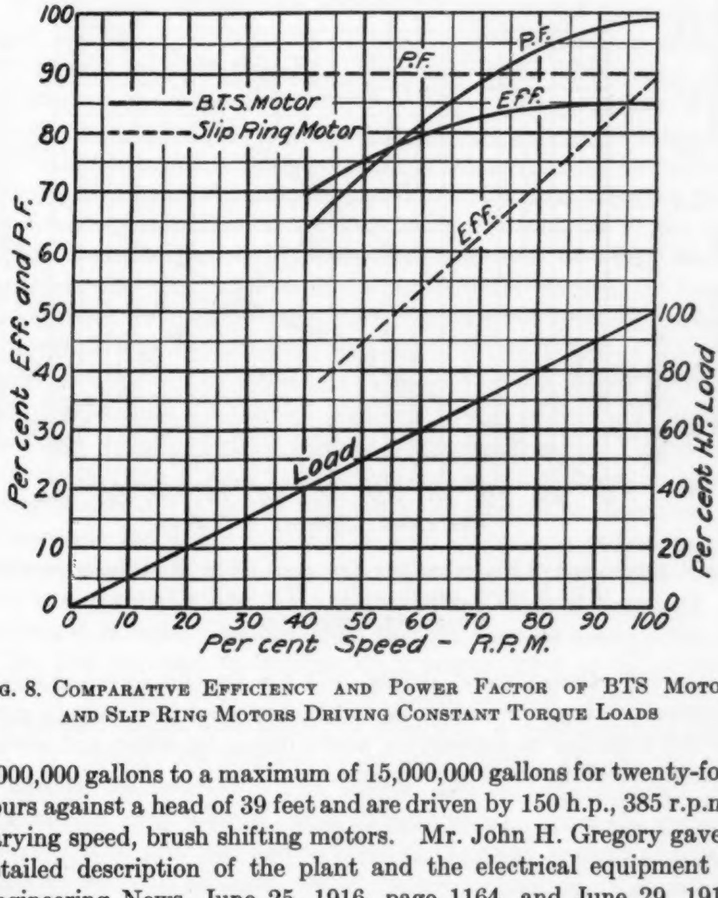


FIG. 8. COMPARATIVE EFFICIENCY AND POWER FACTOR OF BTS MOTORS AND SLIP RING MOTORS DRIVING CONSTANT TORQUE LOADS

5,000,000 gallons to a maximum of 15,000,000 gallons for twenty-four hours against a head of 39 feet and are driven by 150 h.p., 385 r.p.m., varying speed, brush shifting motors. Mr. John H. Gregory gave a detailed description of the plant and the electrical equipment in Engineering News, June 25, 1916, page 1164, and June 29, 1916, page 1224.

While the brush shifting motor has finer speed control and better efficiency when operated at reduced speeds it does not follow that

it is better than the slip ring induction motor for all applications. If only 10 per cent speed reduction is required for a short time during the day, then unquestionably the slip ring induction motor will show up better than the brush shifting motor. However, this type of

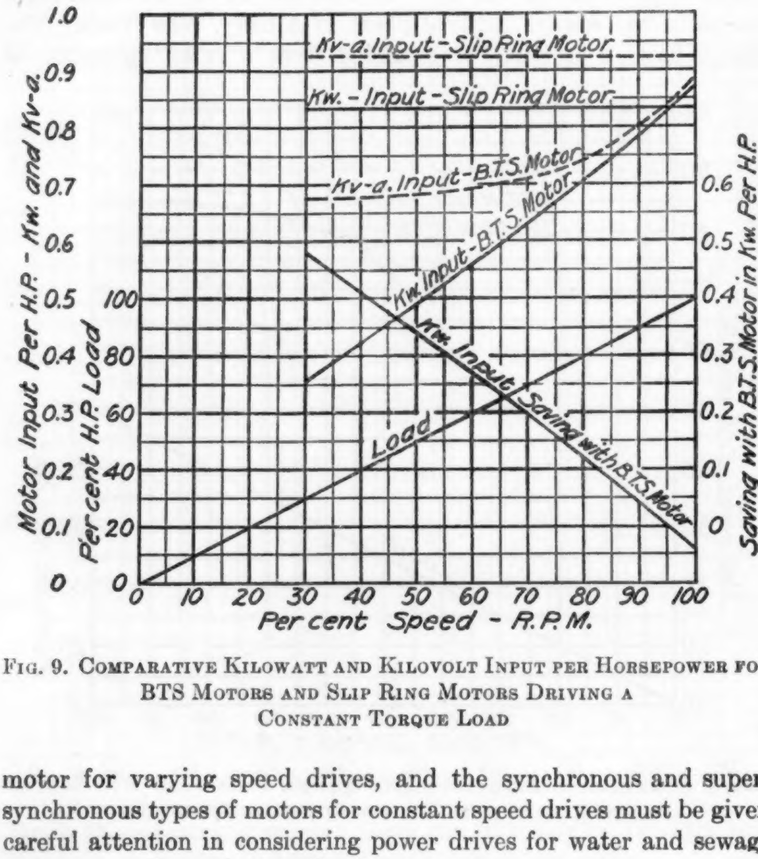


FIG. 9. COMPARATIVE KILOWATT AND KILOVOLT INPUT PER HORSEPOWER FOR BTS MOTORS AND SLIP RING MOTORS DRIVING A CONSTANT TORQUE LOAD

motor for varying speed drives, and the synchronous and super-synchronous types of motors for constant speed drives must be given careful attention in considering power drives for water and sewage pumps as well as other applications.

MUNICIPAL TEAM WORK[1]

By Frank C. Jordan[2]

It is an accepted fact that coöperation between the water department and other departments of the city government is essential to the well being of the city. Municipal Team Work is of vital importance in the development of a City. The American Water Works Association will render a worth-while service to humanity if it is instrumental in bringing about a better spirit of coöperation between the water department and other city departments. It is not for our Association to set up rules for the conduct of the Fire Department, the Board of Health, the Department of Public Works or any of the many city departments, but the Department which we represent is morally obligated to make every attempt towards coöperation with the other departments and thus to set an example which possibly will be followed to a greater or less degree by other city departments. A careful scrutiny of our efforts will disclose any effort or lack of effort towards proper team work. "Love thy neighbor as thyself" would not be half-bad as a motto for the public utility operator. It is not the intent of this paper, however, to to persuade the utility operator into an attitude so radical in the business world. The Biblical injunction is cited not in the hope that it may in this day and age be applied in its entirety. It is mentioned in order that one small tangent may be drawn from it.

The first requisite to building up a proper spirit of coöperation and the bringing about of proper team work is neighborliness. The clever business man, utility or otherwise, avoids deceiving himself. If he loves his neighbor as he does himself, he does not try to deceive his neighbor. You cannot deceive your neighbor for long and get away with it. It is all right to brag about the mileage you get out of your car, and to boast of the small amount of repair bills you pay, it is all right, too, if you are so inclined, to set up as as righteous citizen, and all that, but your neighbor knows you;

[1] Presented before the Detroit Convention, May 23, 1923.

[2] Secretary, Indianapolis Water Company, Indianapolis, Ind.

he sees how often you are under the car there in the garage and he knows how late you sit up or stay out nights.

The same thing is true in the utility business. The whole community you serve is made up of your neighbors. Your neighbors know, sooner or later, just about all there is to know of your affairs. This being true, the intelligent utility operator is the operator who tells the world what he is doing, why, how, when, and where.

We hear a great deal about the popular latter-day mysterious and intangible thing called "public relations." We listen to, and read, long and expert papers on the subject, but down under the surface we gloss over with phrases is the undeniable fact that public relations, so called, consist of nothing more or less than neighborliness. The operator who is a good neighbor to all his community, who treats his neighbors fairly, serves them well, charges them properly and carries his share of the community load in all respects never has one of these lately discovered public relations problems.

The utility operator who works with his city officials, as one neighbor with another, never has such a problem. If he is acquainted with these city officials, as one neighbor knows another, it follows that the officials will know his problems of operation and will sympathize with him as one neighbor with another. It is only when we keep away from the officials, and behave as perfect strangers to them, that difficulties arise.

There may be some who will say that it is well to keep a respectable distance between city or state governmental officials and the utilities. The trouble with this theory is that this distance leaves space that may quickly and readily become filled with misunderstandings, mistrust and even enmity.

It all simmers down to this: the problems of the utility, which are service and rates, are community problems. The utility cannot solve either one by itself. Neither can the community through its city or state officials. Both problems are bigger than either the utility or the officials. They must be solved for the common good of both; therefore, the thing to do is to maintain friendly and neighborly relations towards each other. Such neighborliness tends towards municipal team work.

In an attempt to bring about efficient municipal team work in the City of Indianapolis we became neighborly with the various city departments and the results have been most gratifying. We held neighborly conferences with the Fire Department, and these

have resulted in a more efficient public fire service. In a neighborly way we invited the fire chiefs, fire captains and lieutenants to visit our plants and they accepted our invitation. They evidenced great interest in the operation of our pumping units, boiler room, etc., and a great majority of them confessed that it was their first visit to any of our properties. We returned their call and many of our men had to confess that it was the first time that they had had the opportunity of receiving first hand information in regard to the trials and tribulations of a city fireman. This neighborliness has made their problems our problems, and our problems theirs. In one of these neighborly conferences, the question of decreasing our fire loss came up for consideration and it was only natural that we should join hands in a Fire Prevention program and the Indianapolis Fire Prevention Campaign was the result of these neighborly talks.

During the first eighteen months of our Fire Prevention Campaign we held neighborhood meetings in every section of the City, and through the instrumentality of moving pictures, addresses and contests, the value of fire prevention measures was impressed on the minds of the Indianapolis public and they are now evidencing an exceptionally fine spirit of coöperation as the result of these little meetings when two or three hundred neighbors gathered in a fire engine house or public school building to plan for a cleaner and safer Indianapolis. At this time our attention is largely centered on a Clean-Up and City Beautification program and a Campaign for the Elimination of the Wooden Shingle Roof, and we are receiving most satisfactory support from the great majority of Indianapolis citizens. During 1922 the Building Commissioner issued approximately 4000 re-roofing permits, and at the present rate this number will be almost doubled during 1923. In this great campaign for a cleaner, safer and healthier Indianapolis, we have witnessed municipal team work second to none in the history of our City.

History has shown that it is rather unwise for one neighbor to point out the defects in another neighbor's household, and bearing this fact in mind, we called in the National Board of Fire Underwriters to make a most careful study of the fire and water departments and we then joined in a neighborly effort to eliminate those defects which were brought to our attention by the exceedingly efficient gentlemen from the National Board's office. A movement is now on foot to give Indianapolis a re-classification in its insurance

rating, and our citizens will profit because of the municipal team work in building up the public fire service.

We held some very pleasant conferences with the City Board of Health, and, in a consideration of the physical conditions in Indianapolis, we discovered that many of our citizens were under-privileged in that they did not have the privilege of living in modern homes equipped with bath, toilet and other modern sanitary conveniences. In company with city officials, we visited several of these properties and found that many of these under-priviliged citizens were very desirous of making their properties modern, but that their financial condition precluded such a transformation. The Board of Health gave consideration to the enactment of very stringent measures, which would compel the installation of sanitary conveniences. A brief consideration of this proved that it would not be the neighborly thing to do unless the city was able to show that these conveniences could be installed without considerable financial embarassment to these under-privileged citizens. A few more neighborly conferences were held and a plan was formulated under which plumbing is being installed on the partial payment plan and a sanitary program of vital importance to the health of Indianapolis is being carried through with practically no friction whatsoever.

The City Health Department is morally obligated to rid the City of disease breeding places, and the Water Department must bear a share of the Health Board's obligation in this matter. It is, therefore, of vital importance that some financial arrangement be made under which every citizen may have the benefit of thoroughly sanitary quarters. The payment, or budget plan, is being utilized by quite a number of our citizens and we have found that an advertisement of the payment plan of plumbing installation is all that is necessary to bring people to the plumbing supply house, and in many cases they are able to take care of the financial arrangement without resorting to the payment plan. This budget plan is working very satisfactorily and is serving a great purpose.

In one of our neighborly conferences with some of our patrons, some question was raised in reference to our rules and regulations. The friendly advice of the Public Service Commission was sought and as the result of some further conferences a Committee, consisting of bankers, manufacturers, lawyers, club women, waterworks men, college professors and other citizens, to a total of twenty-five, met, in a neighborly way, to formulate waterworks rules which would

be fair both to the utilities and to the balance of the public. This Committee has held several meetings and these rules are about ready for submission throughout the country. The fairness of these rules is an indication of the public's desire to be fair when the utility presents its case in the right manner.

In our program of coöperating with the Board of Public Works in the up-building of our City, we have been called upon to make very large expenditures in water main extensions, many of which are not paying investments, but which are of inestimable value to the Indianapolis citizens. In carrying out such a program, entailing large expenditures, it is necessary for the state and city authorities to pursue a broad-gaged policy.

In an attempt towards neighborly coöperation with the Park Board we have done a considerable amount of work in beautifying the grounds around our pumping stations and we are looking forward to the day when every part of the water company's property will be a beauty spot and will mould itself into the great plan of city beautification.

We have most friendly relations with the school children and the publicity which they have given us is of tremendous value. Every pupil in the upper grades is required to write an essay on the public water supply of our City, and during the course of the year a great many of the classes visit our filtration system and pumping stations and very little of interest escapes their notice. We recently furnished the school children with pamphlets descriptive of our property and these pamphlets are being utilized as the foundation for thousands of essays. A great many of our new patrons volunteer the information that a school boy or girl in their home has insisted upon having sanitary conveniences in the home. In this, and in other ways, it has been demonstrated to us that the water company can have no more valuable asset than the good will of the school children of the city.

Our City is blessed with an exceptionally large number of civic and commercial organizations, the records in the local Chamber of Commerce showing a total of more than one hundred groups of people organized for the purpose of up-building the city. One of our many trips of inspection included representatives from 92 of these organizations and no publicity expenditure made by our Company has been productive of better feeling than this inspection trip, when men and women from every section of Indianapolis

spent a full afternoon and evening in an inspection of our properties and a consideration of the future development of the public water supply.

It has been gratifying to find that our attempts at neighborlines have been reciprocated in a greater degree than we had any reason to expect. Almost without exception our citizens have assumed a most neighborly attitude and there is being carried forward a municipal team work which is resulting in great good in our City.

FROM COAL TO WATER[1]

By George Nelson Schoonmaker[2]

The City of Toledo's water supply is pumped by a single station known as the Broadway High Service Pumping Station, located on Broadway about $2\frac{1}{2}$ miles from the business center of the City.

The present plant is situated on the site of the old original plant and is, comparatively speaking, an entirely new plant enveloping the original one. This operation was carried out by piecemeal construction over a period of five years, during which time no interruptions to service occurred.

During the year 1920, serious consideration was given to the thought of securing maximum operating efficiency at this station, chiefly for two reasons: that operating costs had made a tremendous increase during and since the war, especially in fuel costs, and that the station was practically new both as to boilers and pumps and it was natural to conclude that increased efficiency must be possible.

Accordingly, a general survey was made of the power-producing as well as the power-consuming units and their auxiliaries, from which conclusions were reached as to their relative economy of operation.

For an accurate determination of many of the questions involved, meters of various types were necessary to uncover much of the information desired. A description of these and the results from their use are the purposes of this article.

COAL SUPPLY

The coal supplied to this Station is purchased under rigid specifications and all coal used must not only meet these specifications, but, of greater importance, must satisfactorily perform under actual operating conditions.

[1] An article describing the cycle involved in the pumping of filtered water at a modern pumping station. Every element is assisted in an effort to produce the best results obtainable, through the use of various types of indicating and recording devices, working on and in conjunction with up-to-date equipment.

[2] Assistant Commissioner, Division of Water, Toledo, Ohio.

Coal is delivered by rail, unloaded, crushed and conveyed by a Jeffries crusher and conveyor system, attached to which is a 1 ton capacity hand operated Beaumont coal weighing larry, which delivers

FIG. 1. BROADWAY HIGH SERVICE PUMPING STATION

the coal after weighing to the stoker hoppers. A careful check is made upon all coal charged against each boiler unit, both by weighing

preliminary to dumping (record of which is kept by the fireman), as well as by a counter on the lever attached to the dump gate, which

FIG. 2. SIMPLEX PITOT TUBE RECORDERS AND BOILER FEED METER

corroborates the number of charges, with their corresponding weights, delivered to each hopper.

FEED WATER

This at present is furnished by returning all condensed steam from the condensing units. The additional amount necessary, approximately 20 per cent, is raw make-up water. There is at present installed a two-effect Griscom-Russell Evaporator System which will be placed in operation, as soon as some existing irregularities in the plant are overcome.

All boiler feed water is metered by a Simplex, Type G, meter attached to a 3-inch x 1½-inch Venturi tube in the main boiler feed line. There are also auxiliary 2-inch x 1-inch Venturi tubes, one for each boiler unit. These are arranged in such a way that, if desired, the meter may register the feed to any single unit.

All feed water is delivered into a Worthington-Stillwell type, open feed water heater rated at 2300 h.p., with a capacity of 69,000 pounds of water per hour, equipped with trapped over-flow and oil separator. Feed water is heated to approximately 200°F. before delivery to boilers.

AIR SUPPLY

The air supply for combustion is furnished by a Sturtevant blower fan, directly driven by a Sturtevant vertical steam engine. There is also a reserve unit in case of breakdown. Another of the same type of engine is connected to the line shaft and drives the stokers.

DRAFT

Natural draft is provided by a 225-foot Heine radial brick chimney.

STEAM PRODUCING EQUIPMENT

The steam producing equipment consists of one battery of 2 units B. & W. Stirling type boilers, each with a 500 h.p. rated capacity. Connected to these are two five retort, extra wide, Sanford Reilly underfeed stokers, each having 65 square feet of effective grate surface and one battery of 2 units McNaull type Boilers, 500 h.p. rated capacity, also equipped with two five retort, standard width, Sanford Reilly underfeed stokers, each having 52 square feet of effective grate surface.

STEAM CONSUMING EQUIPMENT

The main steam consuming pumping units are of interest. These range from the old direct acting Duplex type pumps, installed in

1876, to the newer and more modern triple expansion and turbine driven centrifugal type pumps installed in 1914 and 1920.

In all, there are 6 main pumping units having a combined capacity of 101,000,000 gallons per day, such being as follows:

PUMP NUMBER	MAKE	TYPE	CAPACITY
			m.g.d.
1	DeLaval	Turbo-centrifugal	30
2a	Knowles	Direct acting duplex	6
2b	Worthington	Direct acting duplex	5
3	Allis-Chalmers	Triple expansion	30
4	Worthington	Duplex compound	15
5	Worthington	Duplex compound	15

These, together with all auxiliaries, comprise the steam energy operated equipment.

Pumps 1, 3, 4 and 5 have surface condensers while 2a and 2b have jet condensers. The latter are used only once a week and then only for a sufficient period to assure their operation in case of emergency.

METERS

Each boiler unit is equipped with a Foxboro CO_2 recorder, a Bailey Boiler Meter and a Bailey differential draft gage. The combined units are controlled by a single Simplex, Type G, Boiler feed water meter and the Gray System of automatic combustion control.

Each pumping unit is equipped with a stroke or revolution counter, together with a Simplex Pitot Tube Recorder. Pitot tubes for water flow measurement were selected for two important reasons: first, that the distances between pumps and the main header chamber were not sufficient for the introduction of venturi sections, and second, that in order to install a venturi section, the pumping unit is temporarily out of service. On large units this question becomes important.

Neither of the above situations entered into the application of pitot tubes.

From the standpoint of comparative accuracy (pitot tubes versus venturi tubes), the writer has every reason to assert that as good results as could be obtained with venturi meters are being obtained through the use of pitot tubes at our station. This may be clearly

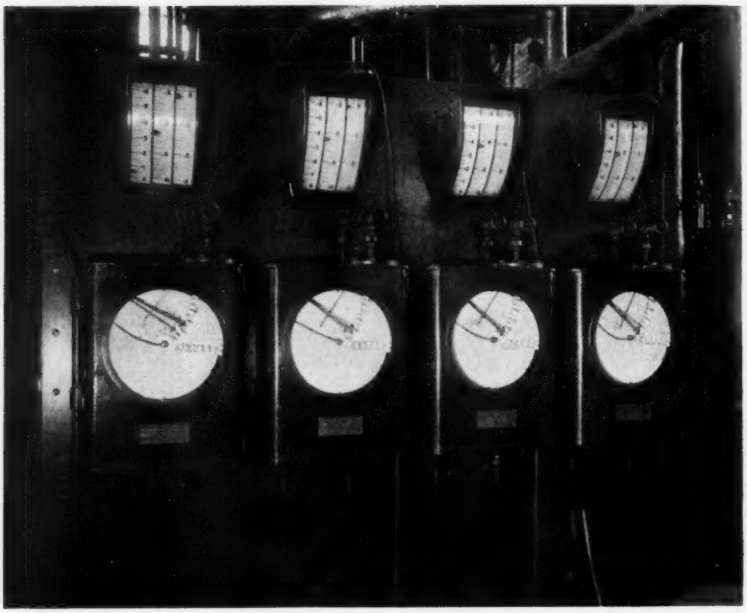


FIG. 3. BAILEY BOILER METERS AND DRAFT GAUGES

FIG. 4. CONTROL PANEL BOARD—GRAY SYSTEM OF AUTOMATIC COMBUSTION CONTROL

seen by investigating log sheets for various weeks and noting the close agreements between the counter and pitot results. Entrained air is a potent source of trouble with almost any kind of a meter and more particularly with pitot tube meters. We have reduced this, however, by giving each pitot tube meter careful attention. They are operated for the elimination of entrained air, if any, each week and a test is made at the same time to determine their accuracy.

The installation of the pitot tubes was comparatively simple. The discharge lines from each pumping engine were tapped and a 1-inch corporation cock was inserted in such a manner that the orifices of the pitot tube are at the center of the pipe.

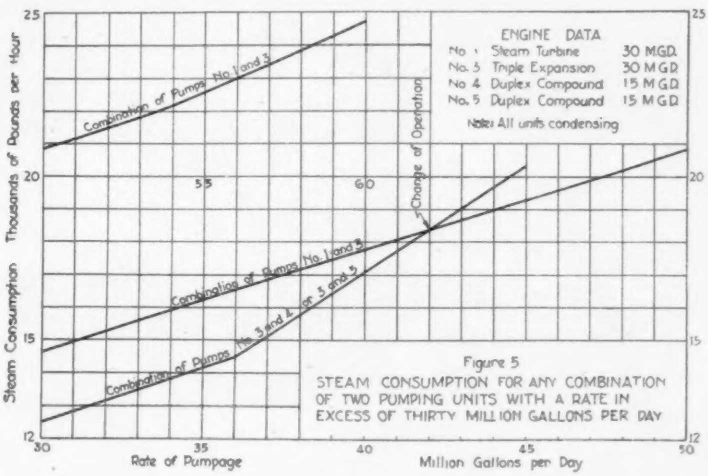


FIG. 5

Since the velocity of the water flowing through a pipe varies across its diameter, being greater at the center and less as the wall of the pipe is approached, a traverse of the main was made to determine this condition or the relation that the mean velocity in the main bears to the center velocity. It is the center velocity that is recorded by the meter. In the interest of accuracy in determining the traverse coefficient, the mains were traversed on two diameters at right angles to each other.

The location selected for tapping the main and making the traverse was in a straight run of pipe at least 20 diameters ahead of any bends or other obstructions which might distort the smooth flow of the water.

Concrete chambers were built over the mains where the pitot tubes are located. These were made large enough to permit the removal of the pitot tubes at any time for inspection or for traversing the main on each of the two diameters. Two 1-inch galvanized iron pipe lines were used to connect the pitot tube with the recording meter on each pump discharge line. These were carefully laid with a continuously rising grade and chambers were installed at the high point for the collection of air that might be entrained in the water. An air release valve was provided on each chamber.

FIG. 6. ANALYZING PREVIOUS DAY'S RESULTS

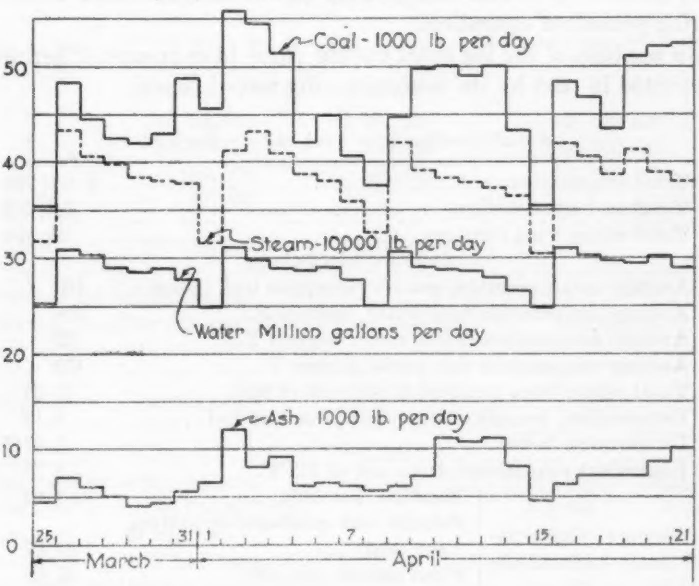
Manometers are mounted on the wall to the rear of the recorders. These serve as indicating meters to the operating engineers, and are the basis from which all daily operating conditions are synchronized, through the use of combinations of pumps for various varieties of station loads. See figure 6 for steam consumption of various units at varying loads.

The liquid used in the manometers is a mixture of carbon tetrachloride and benzine. The specific gravity of the liquid for pumps 2a and 2b is 1.20, for 3 it is 1.40 and for 4 and 5, 1.30.

The different specific gravities were selected so that the deflection of the liquid would at all times be large enough for accurate readings. Where the velocity of the water in the main was low, as in pumps 2a and 2b, a light liquid of 1.20 specific gravity was used, while for pump 3 where the velocity to be measured was higher, a liquid of 1.40 specific gravity was used.

Figure 7
RESULTS OF OPERATION
BROADWAY PUMPING STATION - TOLEDO, OHIO

Data:
- Coal weights taken from hopper track scale
- Evaporation taken from Bailey meter charts - Stirling Boilers.
- Daily pumpage taken from Simplex pitot charts
- Total ash as weighed
- Time cycle, March 25th to April 21st 1923



From the charts of weekly operation of boilers and engines, it is clear that the Pitot tube recorders are giving satisfactory accuracy especially on the No. 3 pumping engine, (triple expansion). On the others, the discrepancy is due to slippage, this being especially true of pumps 2a and 2b and of pumps 4 and 5, at reduced rates of pumpage.

All charts from the recording meters are changed, analyzed and their results computed daily, by a trained employee engaged in this

work. At the end of each week, a record chart for permanent filing is produced.

A careful perusal of the information submitted by meters enables us to check the following: The condition of the boilers, i.e., their ability to burn satisfactorily different kinds of coal, and the necessity of increased or decreased air supply in order to do this. The Bailey boiler meters and draft guages together with Foxboro CO_2 recorders provide such information.

The condition of pumping units, as to length of stroke, operation of valves, and condensers. These elements are controlled by Simplex Pitot tubes and ordinary water meters, metering the condensate from each pump condenser.

In general, all meters immediately record inconsistencies occurring during periods of operation.

An analysis of the log sheet ending April 14 is presented herewith, supported in part by the accompanying record charts.

Results analyzed for week ending April 14

		Pounds
Total evaporation		2,630,760
Total coal consumed		321,285
Total refuse from furnaces		59,100
Data for heat balance		
Average steam pressure, pounds per square inch (gauge)		160
Average temperature feed water, degrees F.		188
Average temperature boiler room, degrees F.		72
Average temperature flue gases, degrees F.		470
Total refuse from furnaces in per cent of fuel		18.39
Evaporation, pounds of water per pound of fuel		8.18
Evaporation factor		1.0717
Equivalent evaporation from and at 212°F.		8.77
Average approximate coal analysis	Moisture, per cent	1.92
	Volatile and combustible matter, per cent	31.07
	Fixed carbon, per cent	53.00
	Ash, per cent	14.01
Average heat value per pound of coal b.t.u.		12,645
Average combustible in ash (per cent of refuse)		23.8
Fuel gas analysis	CO_2 per cent	10.3
	O_2, per cent	9.0
	CO, per cent	0
	N_2, per cent (by difference)	80.7

Heat balance per pound of coal

	B.T.U.	PER CENT
Heat absorbed by boiler	8,510	67.3
Loss due to evaporation of moisture in fuel	24	0.19
Loss due to heat carried away by flue gases	1,645	13.0
Loss due to unconsumed carbon in the ash	649	5.14
Loss due to: Burning of H_2; Heat carried away in refuse; Operation of soot blowers; Radiation and unaccounted for	1,847	14.37
	12,645	100.00

Engine room

PUMP NUMBER	TOTAL PUMPAGE FOR WEEK (PITOT TUBES)	STEAM CONSUMED	DUTY FOOT POUNDS PER M POUNDS STEAM
	gallons	*pounds*	
3	178,733,000	1,482,650	169,000,000
4	12,548,000	262,550	66,300,000
1	4,604,000	58,150	111,000,000
2a, 2b	171,000		
	196,056,000	1,803,350	
Average net pumping head			168.4 feet
Average duty for the week (pumps 1, 3 and 4)			152,250,000 ft. lbs.

Steam balance for plant

	POUNDS	PER CENT
Steam used by prime movers	1,803,350	68.56
Steam used by turbine generators	170,750	6.48
Steam used by air compressor	100,800	3.83
Steam used by park heating system	72,600	2.76
Steam used by boiler room auxiliaries	263,076	10.00
Steam used by other small auxiliaries; Steam used by pumps not in operation; Steam unaccounted for	220,184	8.37
Total	2,630,700	100.00

The Division of Water of the City of Toledo expended approximately $35,000.00 in the purchasing and installing of most of the equipment mentioned. We are confident that results so far obtained,

after practically one year of use, demonstrate that this initial cost will be absorbed in a relatively short space of time. In fact, during the year 1922, 6822 tons of coal were used in pumping 10,561 millions of gallons of water as against 6569 tons used in 1921 for pumping 9276 million gallons or, we pumped one million gallons of water with 124 less pounds of coal in 1922 than we did in 1921. This means a saving of 650 tons over the previous year or about 10 per cent of all coal used. Translated into money, it means a saving slightly in excess of $4,000.00 for the first year, based on the average price of coal during 1922.

The time was never more opportune for the elimination of all waste than the present. This refers more particularly to the production of power and when such power is produced through the medium of steam. The day is rapidly approaching, and in a few circumstances has passed, when fuel for power development can be wasted. We are realizing, as never before, that during and since the war the fuel reserves of the United States are one of our greatest assets, and the producers of this most necessary of all commodities have practically placed a premium upon it.

We are endeavoring in a small way to show how much of the heretofore disregarded waste may be eliminated and what such elimination means when calculated in dollars and cents.

This has been done by the introduction of various types of meters and other devices for the detection of waste and improvement of overall plant efficiency. As practical water works men, I am sure we believe in the general utility of the water meter, and if this be true, it should follow that we ought to be consistent and check our production as well as our distribution, eliminating in the meantime all waste.

Some interesting developments will be uncovered when this is done. In our own case, the outstanding fact was the marked divergence in the ability of our boiler firemen. At the present time, we have educated them to produce results according to established rules which have since been laid down for their guidance. I am pleased to say, in general, these are being followed and we are consequently getting fairly good results.

It must be admitted that all kinds of coal cannot be successfully fired, because as soon as this occurs the entire boiler room is thrown out of balance, new calculations have to be made for a new change of conditions, air flow altered and the like. What is meant by the

previous statement, however, is substantially this: secure a good grade of coal, which under all conditions meets your requirements, burn it in such a manner through the proper operation of your boilers and their auxiliary equipment as to get every single heat unit out of it, and, finally, know where all these heat units are distributed throughout each day's operation.

Most pump manufacturers, when selling pumping equipment, sell it with definitely established duty guarantees from which curves may be plotted showing steam consumption from one-quarter to full load. In stations where there are a variety of pumps, a duty test should be run with various engines in service and, from such tests, curves of duty of various combinations of pumps for any variation from minimum night to maximum day load may be established. Then and then only will your operating engineers know when and where to make changes, keeping the more efficient units on the line for the particular condition and the less efficient off.

Finally, the easiest way to add to net profits is to cut costs and reduce waste. One place to do this is in the average boiler room. The easiest method of doing it is to employ instruments to supply information as to where the leaks, losses and wastes occur, and how much they aggregate. The boiler room is an expensive place to use guess methods. Get your furnace a cash register.

ESTIMATING BILLS[1]

By W. C. Hawley[2]

There are few more perplexing duties which the waterworks manager is called upon to perform than estimating what is the proper and just amount of water to be charged for when the meter has stopped registering. Fortunately, a very small percentage of the meters in service fail to register and, again fortunately, in the majority of such cases there is little difficulty in making a bill to which there can be no reasonable objection on the part of the consumer; but there are occasionally cases for which it is extremely difficult to find a satisfactory solution.

The problem has to be considered from various angles. The conscientious manager, in these days of abnormal costs, wishes to see that his department or company receives what it is honestly entitled to and in this he is not asking the consumer to pay for service he did not receive. But, can he, with the information available, make a bill which he believes equitable and which will be satisfactory to the consumer? Or, supposing that he makes a bill which he believes to be just, but which the consumer may dispute, how will the Public Service Commission view the matter? It must be kept in mind that few public service commissioners have had waterworks experience. They may not share with the waterworks man the confidence in the water meter which his experience has given him, but rather incline to the more or less general distrust of the meter on the part of the public.

Again, it may be considered advisable to accept a loss by making a bill on such a basis that there can be no dispute, rather than to take the chance of a complaint. This may be good policy as far as avoiding present trouble, but it is discrimination against the other consumers, where meters have registered properly, and in all probability will only defer the complaint until the consumer gets a bill

[1] Presented before the Detroit Convention, May 24, 1923.

[2] Chief Engineer and General Superintendent, Pennsylvania Water Company, Wilkinsburg, Pa.

based upon actual meter registration which is larger than the estimated bill.

Some of the public service company laws or the commissions operating under them have ruled how bills shall be made where the meter has stopped registering. The registration of the previous billing period or the rate of registration of a new meter or of the old meter after it has been repaired for a certain period are among the rules laid down. For men so unfortunate as to be working under such conditions there is nothing to do but follow them, but it is worth while in passing to point out that such laws or rules are unjust. In many cases they are undoubtedly the right rules to follow, but in others they will result in gross injustice, sometimes to the water utility and sometimes to the consumer. It is to be regretted that such questions have to be solved by rule rather than by the judgment of men of experience and of proved ability and integrity, guided by the Golden Rule and an honest intent to give a square deal.

It is well to keep in mind that, as a general rule, if any reasonable question arises in making an estimated bill, the benefit of the doubt is given to the consumer. This does not mean that that method of computation which makes the smallest bill should always be used. There may be two or more possible methods of computation and a study of the available data in the case may indicate that it is more reasonable to use a method giving a larger bill. But, if two or more methods are possible, without data to warrant choosing one method as preferable, then the only thing to do is to use the method giving the smallest bill.

Where bills are sent out each month, the difficulties in making estimated bills will be less than where the utility is on a quarterly or semi-annual basis, because the period covered by the estimate is shorter and the bill correspondingly less. Meters should be read at least quarterly, even though bills are sent out only twice per year. In cases where rather large quantities of water are used it is good practice to read the meters each month or even oftener.

It is important that the fact that a meter is not registering should be discovered at the earliest opportunity. The meter reader should therefore be given instructions to pay particular attention to this matter. In case the registration for the period is less than ordinary he should open a spigot and watch the one foot hand to see if the meter is registering. The meter books, when returned to the office

after reading, should be carefully inspected and all suspicious readings should be listed and inspectors sent to make check readings. This will be found worth while, not only in picking up meters which are not registering and have been overlooked by the meter reader, but in the elimination of mistakes in meter reading and thus saving trouble over incorrect bills.

The necessity for making an estimated bill comes to us in this way. The meter reader reports that the meter on a certain property has stopped registering. If the meter reading indicates that the meter has registered since the last previous reading, it is only the regular billing period which the estimate has to cover. If the meter reading is the same as the former one, it indicates that the meter had stopped registering prior to or about the time of the previous reading. If the amount registered during the previous period was less than usual and has been billed and paid for, the question arises, can a corrected bill be sent out and collected? We shall assume, however, that the estimate is to cover one billing period only. When the rate of registration for several quarters past has been fairly uniform, that rate may be used as the basis of the estimate and ordinarily the estimate will be accepted without objection by the consumer. If there is a slight seasonal variation it may be better to use the registration for a previous corresponding period. Even then there will probably be an occasional demand for a reduction. The concrete walk was built during the previous quarter; or the washing was done at home during that quarter and sent out during the last quarter; or "Aunt Mary was visiting us during that quarter and she took a bath every day!" and you are supposed to know just how much to reduce the bill to allow for Aunt Mary's ablutions. And here the writer wishes to comment upon the fact that, in almost thirty years experience, he has never had a consumer come in with a complaint that a bill was not as large as it should be. This comment is not intended as a reflection upon the honesty of the water consumers, but rather as indicating a very satisfactory performance on the part of the billing clerks from the consumer's standpoint.

In cases where the rate of registration has not been uniform it may be advisable to use as a basis the rate of registration for the period immediately preceding the billing period or to use, at least as a check, the rate for a period of three or four weeks after a new meter, or the old meter repaired, has been set. If there is a material

difference between the rates of registration immediately before and after the period to be billed, it may be best to use the average of the two rates as the basis for billing if the two periods were of about equal length. If they were not, probably the best solution will be made by the use of squared paper, using the horizontal scale for time and the vertical scale to represent either the meter readings or registration. By prolonging the lines into the period for which the registration is to be estimated until they intersect we can find the probable date when the change in rate of registration took place and thus determine approximately the periods during which each rate of registration occurred and the total amount.

For the more complicated problems of this kind the use of squared paper will be found very helpful. With the record of registration thus shown graphically, facts are disclosed that are not readily discovered by the most careful inspection of the meter reading sheet or by calculation. It is well to go back for a considerable period, two or three years in some cases, and the more readings that have been taken, the better. This will give information of any changes in rate of consumption and will show up an actual dropping off in registration of the meter such as happens when the gear train gradually wears out. One of the best features of the use of squared paper is that in case of a disputed bill a customer is more easily convinced than he can be by any calculation. The facts are presented in a way which a person of ordinary intelligence can understand and the chances for argument are reduced to a minimum.

Some of the most perplexing problems in the making of estimated bills occur where a meter has been registering for years at a comparatively uniform rate and a leak suddenly develops, water going to waste in large quantities. Usually the first knowledge of the waste of water is obtained by the meter reader when he finds that the meter is registering continuously. In such a case he should get the rate of registration by noticing the length of time required to register a convenient quantity. This information may be very valuable in settling a dispute over the bill. The meter reader should also, if possible, make an inspection of the property and determine where the leak occurs and the consumer should be notified of the fact that there is a leak.

Sometimes, in a case like the foregoing, the meter, already in service for some years and with some of its parts worn, is put out of commission by the high rate of registration and there is nothing

to show when it stopped registering or how much water has been taken without being registered. If the leak has not been repaired a new meter should be set at once until the old meter can be repaired and the rate of registration determined. With this information a reasonable bill can be prepared.

If, however, the leak has been repaired before the meter reader discovers that the meter is not registering, it leaves the waterworks man with few data upon which to base a bill. He may be perfectly confident that a large amount of water has been taken, but he has no basis, or at best not a very good one, on which to make an estimate. The fact that the consumer "has never had a big bill before" will be a strong argument against any large bill which is presented.

The foregoing are only a few examples of the problems which are presented from time to time in a waterworks man's experience. It is evident that the manager needs the thoughtful and intelligent coöperation of the meter reader to reduce his difficulties to a minimum. Many of the problems may be solved readily and for the more difficult ones the squared paper will be found helpful. In making an estimate of the water used the manager must study each problem carefully, considering the various possible solutions and the justice of each as between the water utility and the consumer. The figures made in solving each problem should be kept for reference in case of a complaint by the consumer against the bill.

There is bound to be a certain number of complaints against estimated bills, most of which, however, will amount to merely a request for an explanation of how the bill was made. Others will be demands for reduction in the bill and these should be given serious and courteous attention, keeping in mind the fact that, while the bill has been made upon the basis of such information as was available, there may have been other facts which were entitled to consideration. A reduction of the bill when justified by a consideration of the additional facts presented will generally result in satisfaction to the consumer. Occasionally there will be the case of a consumer who merely objects to paying the bill. He has no reasonable basis for a reduction, but comes in thoroughly angry. He may be sincere in feeling that the bill is too large or he may know better and be bluffing. These are the cases that tax the courtesy, tact and patience of the manager. There is no rule for handling them except to let the consumer state his case fully, making notes as he goes along, listen courteously to all he has to say and when he

has finished, his statement may be compared with the records of the meter readers, etc. He may be satisfied or he may not, but in the latter case the manager can feel that he has done his duty and that the consumer in the case is merely one of that fraction of one per cent of all consumers who cannot or will not appreciate courtesy and fair dealing.

ALGAE CONTROL IN TEXAS[1]

By W. S. Mahlie[2]

The algae are subject to much discussion as regards their proper classification into the various groups. The authorities are all more or less at variance as to just where a dividing line should be made.

Certain algae resemble bacteria, others appear to be more related to the yeasts, and still others resemble the protozoa or simple-celled animals. In order to get the algae properly placed in their relationships to other forms of plant life it is proper to show just what position they occupy in the vegetable kingdom.

The vegetable kingdom is usually divided into four large groups as follows:

The seed plants (Spermatophytes)
The fern plants (Pteridophytes)
The moss plants (Bryophytes)
The thallous plants (Thallophytes)

This last group includes the algae, bacteria, yeasts, molds, etc. This group is different from the rest because the members never develop a complete plant body. The dividing line between the mosses and the true algae is not sharply marked, and throughout this entire discussion it must be kept in mind that one form or group insensibly grades over into another, so that at times it is nearly impossible to make a distinction.

The name "thallous" means "a sheath," and the thallophytes are therefore simple undifferentiated plants, never developing roots, stems or leaves. This thallophyte group is further subdivided into three subgroups as follows:

[1] Presented as a lecture at the Texas State Board of Health School for Filter Plant Operators, Dallas, Texas, January 19, 1923.

[2] Chief Chemist, Water Filtration Plant, Fort Worth, Texas.

- Fission plants
  - Blue-green algae
  - Bacteria
- Thallophytes
  - Algae, including seaweeds, pond scums, water silks, etc. Containing chlorophyll
  - Fungi. Containing no chlorophyll
    - Yeasts
    - Molds
    - Mildews
    - Smuts
    - Rusts
    - Mushrooms
    - Puffballs, etc.

The British authorities on algae divide the entire algae world into four large groups, as follows:

The blue	algae consisting of	954 species
The green	algae consisting of	3111 species
The red	algae consisting of	1412 species
The brown	algae consisting of	6265 species

Of which 5000 are diatoms, a great many of which are fossils.

This gives a grand total of about 12,000 species. Of these a large number are marine or salt water algae. The marine forms as a rule are larger than the fresh water forms. Some varieties have been found as long as 1500 feet.

Probably the most authoritative work on algae in United States is that of Rev. Francis Wolle of Bethlehem, Pa. His books were published in 1886. He issued two volumes called the "Fresh Water Algae of United States," which give a complete description accompanied by colored plates which make them very valuable for tracing out unknown forms. He divides the fresh water algae of the United States into three groups;

The red	algae consisting of	17 species
The green	algae consisting of	356 species
The blue	algae consisting of	232 species

He does not include desmids and diatoms in his fresh water algae, but treats them separately. All the species he describes have been found in the United States.

For the algae common to water supplies, Whipple's "Microscopy of Water" is the standard reference, wherein the commoner varieties are described, but not in as much detail as in the other books on algae proper. For all ordinary water purification and investigations his book is the standard for American practice.

In addition to the algae there are other organisms present in water which belong to the animal kingdom, such as,

Protozoa { Rhizopods, Flagellata, Infusoria }
Rotifers
Crustaceae
Polyzoa
Sponges
Higher organisms such as fish, etc.

EFFECT OF ALGAE IN WATER

There was a time when the odors and tastes in water were supposed to be due only to decaying vegetation or organisms, but it has been discovered that such is not the case; that certain forms have characteristic odors, just as an onion odor or a garlic odor is characteristic of those vegetables. Generally however the odor from the decomposing organism is worse than that from the growing one. The diatoms give an odor which is of an aromatic nature generally. The blue-green algae as they are commonly called usually give a grassy or a moldy odor when actively growing, but on decomposition the odor is described as a "pig-pen" odor. The green algae are usually responsible for fishy odors.

Odors and tastes from algae may usually be alleviated by aeration while in many cases those from the animal organisms become worse upon aeration. Actively growing algae appear to be responsible for a great reduction in the pollution of a water supply. One authority, Pettenkofer, goes as far as to say that practically all the natural purification of a stream is due to the effect of the algae.

While the tastes from algae may not be pleasant, there has never been any question in regard to their effect. They are entirely harmless, in as much as they are just like other plants in their composition. A water containing much algae seldom has many bacteria present.

FOOD OF ALGAE

The food of algae consists essentially of the same things as that of other plants. They require carbon dioxide, nitrogen in the form of a nitrate, sunlight and air. The amount of nitrate in water is generally a good measure of its algae growing ability. Sunlight is an absolute necessity. All true algae contain a green coloring mat-

ter, known as chlorophyll. Sometimes it is masked by the color of other substances, but it is always present. This corresponds to the green coloring matter of leaves. It is able by the aid of sunlight to absorb carbon dioxide from the water or air and to convert it into starches. These starches are then converted into sugars by the action of other bodies known as enzymes, and then serve as food for the plant. The following equation shows the action:

$$6\ CO_2 + 5\ H_2O = C_6H_{10}O_5 + 6\ O_2$$

It will be seen that oxygen is given off by the reaction, and if anyone will observe growing algae the little bubbles of oxygen will easily be seen. They serve to help hold the algae to the surface of the water. If either the sunlight or the carbon dioxide is absent, no algae grow.

MULTIPLICATION OF ALGAE

The diatoms multiply by cell division. The cell contents divide or segregate into two portions, a new wall appears between the two parts formed by the cell contents, and finally the diatom separates into two distinct diatoms, each of which goes through this process of division. Diatoms are not generally found joined together in strings or irregular clumps like other algae. Diatoms grow best where the water is circulated. The blue-green algae multiply in a similar manner to the diatoms. Conditions favorable for blue-green algae are shallow stagnant water and relatively high temperature. They sometimes occur in gelatinous masses.

The algae proper, i.e., the green algae, increase in length by cell division, and reproduce by means of spores. Spores are little bodies formed within the cell which have a heavier cell wall than the regular plant cell and consequently withstand more abuse or unfavorable conditions than the plant cell proper. Spores correspond to the seeds of the flowering plants.

There are two general methods of the formation of these spores, the asexual and the sexual. In the asexual method, the spores are formed within the cell and escape through either the side or the end. These escaping spores then vegetate and give rise to new cells, which multiply by cell division, and then reproduce other spores. In the sexual method, there are three types of reproduction. The simplest of these is where the spores are formed within the cell and then escape and meet other spores. Two of these spores meet,

become attached by the little hairs or cilia as they are called, their cell contents become mixed or fused together and a fertilized spore, known as a zygospore results. After a period of time or rest this spore either develops a new plant or breaks up into other spores. In the second type of sexual reproduction, two cells come in contact, and by means of openings in the cell walls the contents from these cells become fused and a fertilized spore or zygospore results. In the third type of reproduction, there are special organs which produce a large female spore called an oospore, which becomes fertilized by small male cells, formed in special organs. The fertilized oospore then vegetates and a new plant results.

ALGAE COMMONLY FOUND IN WATER AND CAUSING TROUBLES

The United States Government made a fairly complete survey about twenty years ago of algae commonly responsible for troubles in water and the data obtained at that time have served as a basis for algae control. The following is a list of the twelve kinds commonly found.

ORGANISM	NUMBER OF CASES	PER CENT	TYPE
Anabaena	27	8.4	Blue
Asterionella	9	2.8	Diatom
Beggiatoa	20	6.2	Higher bacteria
Chara	26	8.1	Green
Cladophora	17	5.3	Green
Clathyrocystis	23	7.1	Blue
Conferva	56	17.3	Green
Crenothrix	13	4.0	Higher bacteria
Fragilaria	19	5.9	Diatom
Navicula	21	6.5	Diatom
Oscillatoria	49	15.2	Blue
Spirogyra	43	13.3	Green
Total	323		

Kellermann in a report showing the geographical distribution of algae showed that Chara, Conferva, Navicula, Oscillatori and Spirogyra are the ones usually reported as responsible for troubles in Texas.

METHODS OF CONTROL

In nearly all the references in the engineering literature we find that algae troubles are encountered with conditions which are not met usually in a rapid sand filter plant. In many cases where troubles have been encountered the water was pumped directly from the storage reservoirs to the consumers without filtration, but with only chlorine sterilization.

Again many cases are on record where there has been trouble in connection with slow sand filters. In other instances after the water had been filtered it was stored in an open clear well. Now in our later type of rapid sand filter plant such conditions are usually not encountered.

Where the stream flow is sufficient, no preliminary reservoirs are built, but the water is taken directly from the river and then filtered. The modern plants all have the clear well covered to prevent contamination.

Where we have large preliminary reservoirs, or clear wells we may treat the algae effectively by giving it the proper dose of copper sulphate.

In a rapid sand plant where we do not have large preliminary basins, and where there is a constant displacement of the water by the incoming water, we have an entirely different proposition. In such cases the walls are usually painted with copper sulphate about once each month, to keep the growth at a minimum, and the algae are usually all removed by filtration. An increased dose of coagulant is effective here. The method of filter handling is usually changed also.

When algae are present in unusually large amounts, the loss of head on the filters will build up quickly, and there will be much more wash water used than ordinarily. When water is "heavy with algae" it will have a sort of silky appearance. Fortunately when the growth of algae is heavy the bacterial content is low. This permits a little juggling of the filters to save wash water.

The following is the method used in such cases. This was used very successfully at Panama by Mr. F. H. Waring, now Sanitary Engineer, Ohio State Department of Health, and also by Mr. J. W. Ellms at Cincinnati, Ohio.

1. Give a regular or full wash to filters at about usual intervals for normal filter runs as if algae were not present.

2. For all full washes cut wash water time to three minutes.

3. Adopt a schedule of one or more intermediate or partial washes using wash water time of one minute.

4. If conditions become acute with filter runs (partial washed) less than one hour, use scheme of disturbing surface clogging of filter as follows: leave sewer closed; shut effluent; turn on full wash water rather quickly and then close; put filter in service again by opening effluent.

This practice of "disturbing" filters may be used once or twice in between partial washings of the filter. If air is available in washing, substitute the air for wash water in the above procedure for disturbing. Throughout the period of algae trouble use chlorine in generous amounts.

APPLYING COPPER SULPHATE TO RESERVOIRS

The usual method of applying copper sulphate to reservoirs is to weigh the proper amounts into a gunny sack, tie it to a boat and drag it through the water slowly, in such manner as to give equal distribution. Another method which has been used successfully at New York is to feed the chemical into the raw water conduit by means of a dry feed chemical machine. This method is especially valuable in times when the reservoirs are frozen over. It is also advantageous because the flow of water through the conduit may be determined accurately and allows a better control over the dosing than if the water is in an irregular shaped reservoir whose contents are naturally more difficult of measurement.

AMOUNT OF COPPER SULPHATE NECESSARY

The amount of copper sulphate required has been carefully worked out by experiment and by actual experience. After the organism responsible for the trouble has been identified, it is only necessary to refer to a table and see what dose is required. The amount of copper sulphate is also influenced by such factors as temperature, organic matter, alkalinity and turbidity. It was recommended by the United States Government to add 2.5 per cent for each degree temperature below 15°C; subtract 2.5 per cent for each degree temperature above 15°C; add 2 per cent for each 10 parts per million organic matter; and add 0.5 to 5 per cent for each 10 parts per million alkalinity. If the carbonic acid is low, add 5 per cent. In general the blue algae take a smaller dose than the green. The amounts of

copper sulphate range from 0.07 to 10 p.p.m. Usually 1 p.p.m. is sufficient.

	PARTS PER MILLION	POUNDS PER MILLION GALLONS
Copper sulphate required for diatoms		
Asterionella	0.20	1.7
Fragilaria	0.25	2.1
Melosira	0.33	2.8
Navicula	0.07	0.6
Synedra	0.50	4.2
Tabellaria	0.50	4.2
Copper sulphate required for blue algae		
Anabaena	0.12	1.0
Aphanizomenon	0.50	4.2
Clathyrocystis	0.12	1.0
Coelasphaerium	0.33	2.8
Microcystis	0.20	1.7
Oscillaria	0.50	4.2
Copper sulphate required for the Schizomycetes or higher bacteria		
Beggiatoa	5.00	41.5
Cladothrix	0.20	1.7
Crenothrix	0.33	2.8
Leptothrix	0.40	3.3
Copper sulphate required for green algae		
Cladophora	0.50	4.2
Closterium	0.17	1.4
Coelastrum	0.33	2.8
Conferva	0.25	2.1
Desmidium	2.00	16.6
Draparnaldia	0.33	2.8
Eudorina	10.00	83.0
Hydrodictyon	0.10	0.8
Microspira	0.40	3.3
Palmella	2.00	16.6
Pandorina	10.00	83.0
Raphidium	1.00	8.3
Scenedesmus	1.00	8.3
Spirogyra	0.12	1.0
Staurastrum	1.50	12.5
Ulothrix	0.20	1.7
Volvox	0.25	2.1
Zygnema	0.50	4.2

	PARTS PER MILLION	POUNDS PER MILLION GALLONS
Copper sulphate required for protozoa		
Chlamydomonas	0.50	4.2
Cryptomonas	0.50	4.2
Dinobryon	0.33	2.8
Euglena	0.50	4.2
Glenodinium	0.50	4.2
Mallomonas	0.50	4.2
Peridinium	2.00	16.6
Synura	0.20	1.7
Uroglena	0.10	0.8

THE EFFECT OF COPPER SULPHATE UPON ALGAE

It is not definitely known just what happens to the algae when copper sulphate is used. In all probability the copper attacks the outer cell wall in the same manner that it attacks cellulose, and liberates the cell contents. Microscopic examination after the algae have been treated appears to confirm this, for the cell contents appear to have been scattered and changed in color.

All of the copper sulphate applied is not used up or consumed by the organisms, but a part of the copper is precipitated out by the bicarbonates of calcium present in the water. For this reason, it is seldom that any copper ever gets into the water in such condition as to be consumed by the people. We have used some rather heavy doses of copper sulphate at Fort Worth and in no case could we ever find any traces of copper in the water after filtration.

Invariably, after copper sulphate has been applied, there is an increase in taste and odor for a few days, due to the decomposing organisms. This is nearly always accompanied by an increase in the bacterial content. Since many of the organisms killed by the copper feed on the bacteria, it is only natural that when these are killed that there will be an increase in the numbers of bacteria.

OBJECTIONS TO THE USE OF COPPER SULPHATE

It has been pointed out that copper compounds are poisonous and for this reason there is much objection by certain people to the use of copper. There objections are usually the result of prejudice and ignorance. In many cases copper compounds are used in medicine in doses ranging from 3 to 15 grains, and some cases are

on record of doses as high as 60 grains. The United States Government says in Bulletin 76, Bureau of Plant Industry, "There is no authentic record of fatal copper poisoning and many of the best authorities do not consider copper a true poison; they hold that it is a natural constituent of the body, and in minute quantities has no effect upon man." On the other hand there is much evidence to show that copper is very beneficial in the treatment of typhoid fever and cholera. In the amount of copper compounds used in water for the destruction of algae there certainly is no cause for alarm.

The argument advanced by a great many objectors to the use of copper is that, when copper is applied to water, a number of fish are usually killed. This is caused by the fact that when the copper sulphate is applied at certain points the water will contain a great deal of the copper which is afterwards mixed and scattered, or diffused throughout the entire body of water. If a fish gets a dose of this heavily laden water he naturally gets into difficulty. But this condition is not characteristic of the entire body of water, and disappears quickly. Many people will insist that if copper will destroy fish it will affect man. When one stops to consider the vast difference between fish and man, the objection will lose a great deal of its force. The following table shows the amount of copper sulphate generally considered necessary for the destruction of fish.

Killing dosage of copper sulphate

	PARTS PER MILLION	POUNDS PER MILLION GALLONS
Trout	0.14	1.2
Carp	0.33	2.8
Suckers	0.33	2.8
Catfish	0.40	3.5
Pickerel	0.40	3.5
Goldfish	0.50	4.2
Perch	0.67	5.5
Sunfish	1.33	11.1
Black Bass	2.00	16.6

The following table will show the various foods and the amount of copper contained in them. The original tables showed the copper present as metallic copper. This has been recalculated in such form as to make it comparable with the form in which copper is used in water.

*Copper in various foods (parts per million)**

	AS METAL	AS SULPHATE
Almonds	36.8	145.0
Apricots	1.0	3.9
Cherries	2.3	9.1
Cocoa	47.0	185.0
Cucumbers	45.0	177.0
Egg yolk	5.6	22.0
Egg white	7.2	28.3
Figs	15.1	59.3
Grapes	1.0	3.9
Kidney (beef)	4.0	15.7
Milk	1.6	6.3
Oatmeal	4.2	16.5
Peas (French)	59.4	233.0
Potatoes	2.8	11.0
Strawberries	8.0	31.4

* Calculated from Jour. Ind. and Eng. Chem., 7, 498.

USE OF CHLORINE FOR DESTROYING ORGANISMS

In late years the use of chlorine has been demonstrated with success in the destruction of certain forms of organisms. Chlorine is especially valuable for the treatment of animal organisms. The dose required is usually much greater than that used for the destruction of bacteria, and consequently there would be a taste imparted to the water. The excess of chlorine, however, is easily neutralized by some reducing agent as sulphur dioxide. This treatment eliminates the objections from the use of copper sulphate. The City of New York has used chlorine for this purpose with much success.

A compound of chlorine and ammonia known as chloramine has also been used successfully by Monfort in the eradication of the troublesome Crenothrix.

EXPERIENCES WITH ALGAE AT FORT WORTH

In August, 1921, our aeration basin was much troubled with growths of algae. There apparently was no increase in the taste and odor from these organisms, but they were very unsightly. In some instances they were stretched out as long as ten feet. These

greenish-brown messes did not look inviting to visitors at the plant. These growths adhered tightly to the sides of the basin and to the aeration nozzles.

At this time we cut the basin out of service and removed the algae by pulling and scraping them away. This was rather a nasty job. After the surfaces were freed as much as possible from these growths we painted the entire inside of the basin with a thick solution of lime. We let this harden a day by air drying before we put the basin back into service again.

For about three weeks no appreciable growth was noticed, but in the next two weeks a heavy growth took place. Upon cleaning the next time, about six weeks after the painting, we had no difficulty whatever in washing off the algae with a stream from the fire hose, whereas formerly it had been nearly impossible.

A little later in the year we painted the walls of our sedimentation basins. Previously to this cleaning we had short growths of algae on the walls extending down about three or four feet from the water line. After painting the walls with lime solution and upon cleaning the next time, about six months later, we found growths extending down nearly 10 feet.

The smooth surface formed by the lime painting prevented the algae from adhering so tenaciously and made it easier to dislodge them with the fire hose. As sunlight is one of the requirements for growth, and when we painted the walls with the white lime we allowed sunlight to penetrate somewhat deeper than previously, the reason for the deeper growth is obvious.

We have observed that the sunlight appears to be of some importance in the color that the algae will take. On the north side of our plant, the algae are of a darker green color than those growing on the south side, while the microscope shows them to be identical in form.

We have noticed also that in some parts of our plant, where the water has a greater velocity than at other parts, invariably the algae do not grow down as deeply on the side walls as at the places where the water has a lower velocity. The rapidly moving water apparently dissipates the light.

These sunlight effects suggest interesting experiments, to determine what effect the different colors would have upon the growth of algae. If we painted the walls white we would have increased growth of algae and increased destruction of bacteria. If we painted

the walls black we undoubtedly would get less algae and more bacteria; conditions favorable for the growth of algae are unfavorable for the growth of bacteria and vice versa.

LIME TREATED WATER AND ALGAE

A rather interesting experience was observed here at Fort Worth during the latter part of April and the early part of May, 1922, while we were having our floods. At this time our entire plant was flooded and when we started operations again, for various reasons we wanted a water containing no free or half-bound carbon dioxide, in other words, water containing a slight excess of lime or caustic alkalinity. After treating the water properly for this condition for a short time we observed that wherever the water reached the algae they were killed. Inasmuch as another of the requirements for algal growth is carbon dioxide, it was obvious that in the absence of this plant food the algae simply died of "starvation."

A POSSIBLE SOURCE OF INCOME FOR SMALLER PLANTS[1]

By Howard A. Dill[2]

Water companies have the advantage over telephone, gas, electric and railway utilities in regard to competition. For that reason, less effort is generally made by water utilities to advertise their product and secure additional consumers, or to increase the consumption of existing consumers. Because water is a necessity and no substitute exists, that is no reason why water utilities cannot obtain additional revenue by a well-planned campaign of advertising and salesmanship. Any superintendent can cite cases of properties supplied with well water, instead of from the water mains in front of such properties. Advertising and personal contact would doubtless convince many persons of the desirability of using city water that is protected by laboratory tests, that may be had by opening a faucet, and that is obtained from an unfailing source of supply, all at a cost of a few cents a day. Baths and toilets would be added in many cases, if an effort were made by the utility to show customers the convenience and sanitary advantages of such equipment. Sprinkling use could be increased by educating the consumer to the effect and enhanced value of a beautifully kept lawn or shrubbery effectively placed about the house.

Water companies could well afford to make a survey to locate properties using well water, and then sell the advantages of city water to the owners of such properties.

Gas and electric companies have demonstrations and exhibitions of their products, and sell equipment to those using these products.

The advisability and desirability of water companies selling material and fixtures at or near cost to customers is a debatable question. There would be objections, of course, on the part of dealers and plumbers, but such a method would undoubtedly en-

[1] Presented before the Detroit Convention, Superintendents' Session, May 25, 1923.

[2] Superintendent, Water Works, Richmond, Ind.

courage the installation of such fixtures. The plumbers, I believe, would be benefited, as the installations would be made by them

In large cities where only city water is used, a possible increase in revenues would be by such methods as indicated.

In smaller cities, however, and perhaps in some cases in larger cities, residences are supplied from cisterns, collecting rain water from the roofs. This requires the additional equipment of a hand pump or of a pressure or gravity tank and an electric motor and pump. By this means softer water is obtained for bath, wash-stand, kitchen and laundry use. It is from this class that additional revenue may be secured. The construction of cisterns is expensive if of such size as to meet adequately the demand. They give trouble from leakage and require frequent cleaning. The electric motor gets out of order and depreciates, and there is also the item of pipe installation.

The Zeolite method of softening water is not new, and is used by laundries, hotels, apartment houses and steam boilers. No additional revenue would be derived from such consumers, as city water would be used by them with or without a softener.

From residents using cistern water, however, there is a decided possibility of increased receipts. A campaign could be made to demonstrate the advantages of Zeolite-softened water, over cistern water, such as its greater softness, cleanliness and reliability.

In the case of new residences, it may be shown that the cost of a Zeolite softener is little, if any, more than the equipment for cistern water. The operating cost of the former is nominal, the salt used costing from $5.00 to $10.00 a year. There is no depreciation, the time necessary in operating is small and the method is simple. There are several makes of softeners, resulting in closer competition and reduced cost.

A cistern and filter of 80 barrels capacity and electric motor will cost about $250.00, as compared with the same amount for a softener to supply a family of four with bath and laundry.

For a family of six, a cistern of 150 barrels, motor, etc., would cost about $350.00, a softener $335.00.

For a family of eight or more, two 150 barrel cisterns, motors etc., would cost about $585.00, a softener about $500.00

Richmond, Indiana, has a population of about 30,000. The water company is a private one, its supply being secured from springs and infiltration galleries, naturally filtered through gravel strata.

The hardness of the water is 20 to 22 p.p.m. Most of the residences occupied by the owners have cisterns, the better class of which use electric or water motors to pump the rain water. Electric motors are gradually superseding the water motor, thus reducing the consumption of city water. Within the past two years, probably twenty new houses have installed Zeolite softeners, several of these through the efforts of the water company.

Advertising is being used, and prospective customers are shown the comparative advantages and costs of the Zeolite and cistern equipment. The Company does not recommend a particular make of softener, but gives the prospect the names of the manufacturers or agents.

The writer installed a softener in December, 1921. The water used the first year for house and back-washing the softener amounted to 37,500 gallons, and the salt used was 600 pounds. If a cistern had been used, the water company would have lost the revenue from the consumption given above.

This is an instance of one possible source of revenue, which we believe is capable of development.

THE IMPORTANCE OF FILTER SAND AND GRAVEL IN FILTRATION PLANTS[1]

By A. O. True[2]

It is probably impossible to state where or at what epoch sand was first utilized by man as a medium for purifying drinking water. Its use was known to the ancients, who undoubtedly observed, at an early date, the effective clarification of ground waters in their natural transit through sandy and gravelly substrata. It is a well known fact that the North American Indians had a regard for pure water. When necessity compelled, they would obtain water from shallow holes scooped in water-bearing sand, rather than draw their supply from a more accessible but muddy stream.

The history of the use of sand, as a water purifying medium, is practically the history of water filtration, for the reason that while many other water filtering media have and are being used, such as coke, charcoal, porous plates and tiles, synthetic silicon dioxide and zeolites, their use has been relatively limited and usually for special purposes. The extensive practical accomplishments in water filtration have been obtained, over a period of nearly a century, by the employment of sand and gravel filtering materials. But it is not the purpose in this paper, to trace the history of water filtration, but to call attention to some of the more common physical properties of sand and gravel, and their relation to present methods in modern municipal water filtration practice.

A few facts in relation to the development of water filtration will be sufficient to indicate the importance of the use of sand as a filtering medium.

The first water filter for the purification of a public water supply on a relatively large scale, appears to have been a filter constructed in East Chelsea, London, England, in 1829. It employed sand as the filtering medium. It was also the forerunner of the so-called slow sand water filter, many of which were put in operation in

[1] Presented before the North Carolina Section meeting, November 15, 1922.
[2] Sanitary Engineer, Proximity Manufacturing Co., Greensboro, N. C.

succeeding years in Europe, and were introduced into the United States about 48 years later.

The reduction in epidemic water-borne diseases, in those cities which pass their polluted river water supplies through a bed of sand, was so remarkable that this type of purification grew rapidly. A number of plants were built in this country between 1880 and 1910.

In 1885, however, the rapid or American type of sand filter for municipal water purification, made its appearance and was destined to have a wonderful growth,until to-day, in this country, probably three times as many people are supplied with water from rapid sand filters than from slow sand filters including the modified slow sand types.

It is unnecessary to inquire or discuss at length why this is so. The rapid sand method has been found more applicable and economical than any other in the purification of many of our surface water supplies, particularly those waters which sometimes carry large amounts of fine suspended particles.

The significant fact is, in relation to this subject, that, throughout the history of water purification, sand has been, and is, the accepted medium depended upon for freeing water from dangerous and objectionable impurities.

The writer believes it has been demonstrated that natural quartz sand of the proper size, uniformity and purity is the most efficient filtering medium obtainable for water purification purposes. Among its desirable physical qualities for this purpose, the most important is indestructibility. It is practically unaffected by the elements and to no large extent by the physical conditions encountered in a filter. Water has no considerable solvent action on sand, nor is sand subject to any depreciation with the possible exception of a slight amount of abrasion from the contact of grains in the process of washing.

Perhaps next to permanency, the most valuable quality of sand as a filtering medium is its high specific gravity. This is an especially desirable and necessary quality in the modern type of rapid filter in which the filtering material must resist by gravity the rapid upward flow of wash water if it is to remain in the filter. The greater weight and resistance of the filtering material, as compared to the smaller dirt particles, constitutes the principle whereby it is possible to separate the sand from the impurities removed in filtration, and to discharge them quickly into the sewer. A relatively pure quartz

sand has a specific gravity of about 2.6. The differential resistance of the sand grains and dirt particles, by virtue of their size and specific gravity will be mentioned again in connection with the conditions in a rapid filter when being washed.

Finally, sand is undoubtedly the cheapest of all materials which may be satisfactorily used as a filter material. In the United States there are many natural deposits of sand, suitable for filter purposes. These are fairly well distributed as to make natural filter sand available to our centers of population without excessively long hauls. Some of the more important deposits of filter sand and gravel, and the companies working them are as follows:

Cape May, N. J.—Cape May Sand Company
Ottowa, Ill.—United States Silica Sand Company, and Ottowa Silica Sand Company
Red Wing, Minn.—Red Wing Filter Sand and Gravel Co.
Montgomery, Ala.—Cook and Laurie Sand and Gravel Co.

The three desirable characteristics of sand, and also gravel, as filtering media, namely, permanence, freedom from depreciation, high specific gravity, and availability at low cost, are readily appreciated by all charged with the design and operation of filter plants.

Sand is not a perfect filter medium in rapid filtration, as at present practiced. Some troubles are reported from the majority of filter plants, which indicate that filter sand has some qualities which render the process less efficient than would otherwise be the case. Whether these difficulties may be attributed to inherent qualities of the sand as distinguished from other filtering media, and if so, to what extent, are questions which cannot be answered conclusively at the present time. The troubles referred to are the tendency in some filters to vertical stratification of the sand after washing, the formation of the so-called "sand balls" and "mud balls" in the upper portions of the sand bed, and the recently reported underwater shrinkage of sand beds.

The consensus of opinion seems to be that the sand ball and mud ball nuisance is attributable not to the sand itself, but to inefficiency of coagulation and the failure of the wash water system to expel and carry away the impurities lifted from the sand surface by the wash water. The shrinkage, under water, of sand beds in rapid sand filters has been reported, as far as I can learn, in only a very

few instances. Some observers report the actual drawing away of the sand bed from the supporting walls of the filter to the extent of a fraction of an inch, and for a considerable depth; with the result that imperfectly filtered water reached the under drains of the filter. Studies in the chemistry and physics of colloids seem to show that many granular substances in the presence of water are subject to an internal force affecting the intergranular spaces and causing a shrinkage of the substance. Clay is a good example of such a substance, and some sands appear to possess this quality. Observation of sand beds with reference to under-water shrinkage, and the best means to prevent or overcome it will be extremely important if it is shown that this phenomenon is of frequent occurrence.

Probably the two most important operations in rapid sand filtration are coagulation and filter washing. They are also the most difficult to control to get best results.

It is an axiom of rapid sand filter operation that filter materials efficiently washed and graded will filter evenly and efficiently and vice versa.

The conditions in a filter, when washed by vertical reverse currents, are familiar to operators. The whole sand bed assumes a semi-fluid, non-resistant condition, due to the dispersion of the sand grains in the wash water stream. A test rod dropped into a filter being washed sinks readily and stops only on reaching the undisturbed supporting gravel at the filter bottom. The dirt accumulated by the filter, together with the coagulant making up the dirt layer on the sand surface, is broken up and dispersed by the upward stream. These dirt particles, being for the most part lighter than the sand grains, are carried upward and beyond the sand, then laterally into the wash troughs and sewer. The smallest sand grains however, under a vertical velocity of water not to exceed 24 inches per minute will rise only about 18 inches, and should not reach the wash trough.

The process is one of rejection of the dirt and retention of the sand by virtue of the selective action of the wash water stream. Two important physical conditions make this separation possible. First, the fact that the dirt is for the most part lighter than the sand, and second, because the dirt particles are smaller than the sand grains and therefore offer less resistance to the washing current.

Since the weight of a particle increases approximately as the cube of its diameter, while its projected area, and consequent resistance to a stream of water, increases only as the square of its diameter, the finer sand grains are carried higher in the upward wash water stream, to points where the latter decreases in velocity. If this is true, it is reasonable to conclude that very fine particles of dirt, or foreign matter, which are as heavy as the filter sand, are carried into the sewer by the ordinary rates of rapid wash.

As the wash water is shut off from a filter unit, the suspended sand bed immediately begins to settle down to its natural position on the supporting gravel in the filter bottom. As this occurs, the law just mentioned with reference to weight and surface resistance again comes into play and tends to cause the largest sand grains to settle most quickly. The result is that, in the absence of disturbing currents, the sand bed stratifies in horizontal layers increasing in fineness of sand grains from the bottom to the sand surface. This places the coarsest sand at the bottom and the finer grains at the top. A bed in this condition offers equal resistance to the flow of the water in the filtering direction and yields the most efficient filtration. The slow closing of wash water valves probably aids in permitting this horizontal stratification of the sand.

Sand is a highly porous material, and a large percentage of the volume forming a sand bed is, of course, space between the grains. In dry sand these spaces or voids amount to from 30 to 40 per cent of the cubical volume.

If for any reason a filter is drained, the voids in the sand bed become wholly or partially filled with air. It is well known that a filter will operate most satisfactorily when these voids are completely filled with water, and that air in the filter bed is troublesome, and in sufficient quantity will completely stop the flow of water through the sand. Another source of air lodging in the intergranular spaces is the water passing through the filter. Under certain conditions of temperature and lowering of pressure, this air separates from the water. In some plants this occurs with sufficient frequency to constitute an annoying feature of operation. The only remedy seems to be careful displacement of the air by a reverse current of water. This raises and fractures the dirt layer and undoubtedly disturbs the efficiency of the filter unless the unit is washed before being again placed in operation.

The sand bed in a modern rapid sand filter is from 24 to 30 inches in depth. Best results seem to be obtained with sands of effective sizes from 0.35 mm. to 0.45 mm. The uniformity coefficient should be not far from 1.6. If the units are arranged for rapid wash the sand surface should be at least 20 inches below the lip of the wash water troughs.

The coarse-grained layer supporting the filter sand is usually referred to as the gravel. There seems to be no set rule as to the diameter below which stone particles are termed sand and above which they are termed gravel. Generally speaking, material $\frac{1}{8}$ inch in diameter and smaller is classified as sand and larger diameters gravel.

In the older air and mechanical wash type of rapid filters the gravel layers are 8 to 12 inches in depth. In the newer rapid water wash type, the gravel bed is about 18 inches in depth. It is usually graded in several horizontal layers from coarsest at the bottom next to, or surrounding, the strainer system to the finest at the top and directly under the sand bed. These layers average some $3\frac{1}{2}$ inches in thickness, the bottom stones being 2 to $2\frac{1}{2}$ inches in diameter and the top layer of gravel being about $\frac{1}{10}$ inch in diameter or smaller.

The purpose of this thick bed of graded gravel is three-fold. First, to furnish a support for the filter sand, which will prevent the latter from being washed into the strainers. Second, to allow the clear water to pass freely and uniformly from the filter to the underdrainage system when filtering. Third, and most important, to distribute the wash water across the entire horizontal section of the filter and to deliver it evenly and without eddies to the sand bed. Eighteen inches of gravel of the sizes mentioned above have been found sufficient to resist the upward force of the wash water when applied at a rate of 15 gallons per square foot per minute, without danger of "blow-ups" or the breaking through of the gravel and a consequent intermixing of the gravel and sand. It would appear that higher velocities of wash water than 15 gallons per minute, equivalent to 24 inches vertical rise per minute, would seldom if ever be necessary. Higher velocities would probably require special arrangements in filter design to prevent loss of sand into the wash troughs. It is questionable if wash water rates higher than 24 inches per minute would be economical.

Every operator should appreciate the necessity of uniform and thorough washing of the sand bed of rapid filter units. As already stated the efficiency of filtration depends upon this. The gravel bed plays an important rôle in securing uniform washing and the consequent settling of the filtering materials in uniformly graded horizontal layers. To obtain these results it is important that the gravel layers be carefully laid, that uniform sizes of stones be secured and level layers of uniform thickness for each size. Only in this way can such a bed be laid as to offer equal resistance to the rising wash water at all points over the horizontal area of the filter bottom.

COLLECTION AND DAILY PUBLICATION OF METEOROLOGICAL DATA BY THE WATER DEPARTMENT[1]

By Scotland G. Highland[2]

A weather bureau, equipped with appropriate instruments for the collection of meteorological data, city soil temperatures, evaporation and stream flow measurements, is an economic necessity at every water-works pumping station.

The practical importance of keeping a record of such data over a long period of years, in each locality, is too apparent to warrant more than brief mention.

At the time of the beginning of the United States weather service, in 1870, and for some years thereafter, the forecasts and storm warnings were looked upon as experiments of doubtful utility. Less than a century ago we knew not whence the winds came nor whither they went, but trained experts are now able, through the aid of daily meteorological observations and the telegraph that joins the places of observation, to trace out the harmonious operations of many physical laws that previously were unknown.

Accurate measurements of frost penetration in city streets is readily seen to be of vital importance to a water department in determining the depth to which water mains and service lines should be laid to avoid the costly action of frost. During the winters of 1911–1912 and 1917–1918, frost penetrated to a depth of five feet in Richmond, Ind., Toledo, Ohio, Lake Forest, Ill., and Bradford, Pa., and five and one-half feet in Detroit, Mich. It is astonishing to note the fact that frost reached to a depth of 6 feet in Buffalo, N. Y., and a depth of 7 feet in exposed places in the city streets of Dubuque, Iowa, North Attleboro, Mass., and Winnipeg, Man.

A water department is powerfully fortified by having available accurate statistics on measurements of stream flow in its locality. Such data will prove a boon to persons engaged in present and future studies of the catchment basin and of the storage question. No

[1] Presented before the Detroit Convention, May 22, 1923.

[2] Secretary and General Manager, Clarksburg Water Board, Clarksburg, W. Va.

matter how small the supply works or the catchment area, the collection and study of facts concerning the atmosphere, soil temperatures in the city streets, and the behavior of water from the time it reaches the earth as rain or snow, are essential to the judicious management of a water department.

Water-works men should not fail to study an annual publication of the water resources branch of the United States Geological Survey called, "A Report on the Progress of Stream Measurements," and a water-supply paper entitled, "Surface Water Supply of the United States," both of which are rich in information on the subject of stream flow.

The 1911 Report of the Pittsburgh Flood Commission, which was organized February 20, 1908, for the purpose of finding means of relief from floods, is a treatise on the subject of the storage of flood waters on the higher tributaries of the navigable streams in the Ohio River Basin. This particular project is of interest to all water-works men because of the fact that increased low-water flow would notably improve the quality of water for domestic and industrial purposes. This report treats on the question of correcting the extravagances of nature by holding the flood waters in seasons of superabundance and releasing it in periods of protracted scarcity. While the project launched by the Pittsburgh Flood Commission was primarily intended to prevent inundations of towns and cities on the Ohio River, incalculable benefits would accrue to all the people of the Ohio River Basin with the establishment of the seventeen reservoirs projected to catch and store flood waters. A similar scheme on any other stream would be equally beneficial; therefore, the question is of wide interest.

With our many thousand of miles of navigable rivers flowing through one of the most extensive and fruitful regions of the world, daily forecasts of the height of water in the various sections of each river are of enormous benefit to navigation, and the warnings issued by the United States Weather Bureau, when precipitation is so heavy as to indicate the gathering, during the near future, of flood volumes in the main streams, are often worth many millions to those having movable property on low grounds contiguous to the streams.

It will be seen that the recital of these facts is not a diversion from the subject of this paper, but rather emphasizes the importance of collecting and preserving necessary data for expediting any such worthy projects. An important fact worth noting is the almost

entire lack of uniformity of behavior between any two streams, which indicates that the discharge of any stream is a law unto itself and must receive individual study of the greatest accuracy, over a series of years.

The splendid work of the water resources branch of the United States Geological Survey and the Pittsburgh Flood Commission calls for a vote of thanks from the water-works fraternity, for the wealth of dependable data on stream flow and precipitation which their reports furnish. It is a regrettable fact that the experts employed by these agencies were unable to obtain from any considerable number of water departments operating within the areas studied reliable data pertaining to precipitation, evaporation, daily height of streams, discharge in second-feet and maximum and minimum temperatures. We who are in the water-works business should know not merely the ordinary operating details, but everything concerning that business which is of practical value to ourselves and others.

Besides affording the opportunity to coöperate in such an important endeavor as flood control, the establishment of a weather station furnishes its share of the information upon which the publication of the United States Weather Bureau, the water resources branch of the Geological Survey, and the weekly National Weather and Crops Bulletin are based. The United States Weather Bureau maintains at the present time 200 full reporting paid stations telegraphing reports daily to the Central Office at Washington for forecasting purposes. In addition to these there are 50 stations of less importance furnishing telegraphic reports at certain seasons of the year for forecasting and other purposes. There are 1000 special observers who render reports in the interest of crops, as the Corn and Wheat Service, River and Flood Service, etc., usually during portions of the year. The coöperative force of the Weather Bureau is made up of 4500 observers; some of these, of course, are included among those who render special reports during a portion of the year. The coöperative observers each day record the temperature and rainfall.

Water-works men will want to establish a fully equipped meteorological station, including soil thermometers, evaporation station, and stream gaging instruments, and to join the United States Weather Bureau's corps of trained scientific observers. A Weather Bureau, equipped with such instruments of standard pattern, has been established at the filtration plant of the Clarksburg Water Board, Clarksburg, West Virginia, where daily records are kept and monthly

reports made to the state Meteorologist of the United States Weather Bureau and the United States Geological Survey, Washington, D. C. The data collected have popular, as well as private and national interest, as evidenced by their being eagerly sought by the local newspapers for daily publication, and read with profit and enjoyment by persons in practically every walk of life seeking information from authoritative sources. It will prove helpful to add local astronomical phenomena to the daily weather calendar published in the newspapers and properly credited to the water department.

In West Virginia there are only two regular Weather Bureau stations from which complete data may be obtained, while there are 113 water-works plants in the state at which full data ought to be collected and carefully recorded. There are 77 coöperative stations in the state furnishing such simple information as temperatures and rainfall.

There is on sale in each state an Almanac calculated for the horizon of the state in which it is sold, that will serve without material variation for every town and city within the state, from which may be obtained local astronomical phenomena, such as the time of rising and setting of the sun and moon, the day's length, and the phases of the moon. If extreme accuracy is desired for any horizon, tables of sunrise and sunset, moonrise and moonset are contained in the American Nautical Almanac. The exact latitude and longitude of any town or city can be obtained from the Director, United States Naval Observatory, Washington, D. C., that office being authorized to compute the values desired. The daily weather forecasts are furnished direct by the Weather Bureau, in Washington. The data collected by the Clarksburg Water Board are published daily without charge in local newspapers, in the following form:

DAILY WEATHER CALENDAR

Tuesday, May 22, 1923

Today's Almanac for Clarksburg, W. Va.
ASTRONOMICAL MEMORANDA

Sun rises	4:40 a.m.	Moon rises	10:47 a.m.
Sun sets	7:14 p.m.	Moon sets	

Day's length 14 hours, 34 minutes

Phases of the moon for May:

Last Quarter	7th	First Quarter	23rd
New Moon	15th	Full Moon	30th

FORECASTS

Fair and warmer tonight; Wednesday unsettled, followed by showers

TEMPERATURES

Highest yesterday.................85 Lowest.............................76

Official Rainfall Records

Rainfall for 24 hours ended 9 a.m. today, 1.2 inches

BAROMETER

Today's barometer 9 a.m. 28.3 rising or falling

Humidity

Relative humidity 9 a.m. today 87

SOIL TEMPERATURES

Today's soil temperatures at various depths, Fahrenheit scale:

At depth of 12 inches 58 degrees
At depth of 24 inches 56 degrees
At depth of 36 inches 54 degrees
At depth of 48 inches 53 degrees
At depth of 60 inches 53 degrees
At depth of 72 inches 51 degrees

STAGE OF RIVER

Height of water flowing over dam 2 feet

STREAM FLOW

Discharge of river in gallons per 24 hours...............1,036,800,000 gallons
Evaporation in 24 hours...0.05 inch
Wind velocity...10 miles an hour

United States Department of Agriculture Weather Bureau, coöperative observer's meteorological station, established at the filtration plant of the Clarksburg Water Board, Clarksburg, W. Va.

Subjoined is given the list of instruments and their uses.

1. An automatic water stage recorder, with weight driven seven day clock. Stream flow measurements were made by the United States Geological Survey by means of a current meter, at stages from zero to flood heights. The expense included railroad fare and subsistence.

2. A set of maximum and minimum registering thermometers, (latest United States Weather Bureau pattern) installed in an instrument shelter with louvred front and sides and perforated botton.

3. A Ferguson Weighing Recording Rain and Snow Gage, equipped with daily clock movement for determining the intensity of rainfall.

4. A United States Weather Bureau standard rain and snow gage. Additional rain gages are installed on each of the principal tributaries of the watershed.

5. A recording anemometer for ascertaining the velocity of the wind, and a wind vane with cardinal points.

Accurate records of the velocity and direction of the wind are essential elements in all meteorological and climatological work, as well as of value to commercial and business interests.

6. A mercurial and an aneroid barometer for determining atmospheric pressure.

7. A whirling psychrometer, United States Weather Bureau pattern, for determining the percentage of relative humidity.

8. Soil thermometers for ascertaining the temperature of the soil at various depths, of the pattern devised for the New York Agricultural Experiment Station.

A separate thermometer is required for each foot of depth investigated and consists of a stout stem graduated and figured thermometer, inclosed in a wooden case, the upper front of which is cut out, exposing the scale, which is eleven inches long, this length being the same for all thermometers. The thermometers are protected by a shelter with louvred front and sides, and elevated three inches above the ground.

9. An evaporation station including an anemometer and a hook gage, for testing the rate of evaporation of water.

Instructions for installing the instruments are furnished by the United States Weather Bureau and the water-resources branch of the United States Geological Survey, Washington, D. C.

In the preparation of this paper no attempt has been made to point out all the known benefits which may result from the establishment of a fully equipped meteorological weather bureau at water-works pumping stations. The data collected and preserved will have a future value beyond any estimate which we may place upon it today.

Patient research by water-works men will bring its own reward and aid in the advancement of a cause of nation-wide interest.

DESCRIPTION OF PITTSBURGH WATER WORKS[1]

By E. E. Lanpher[2]

HISTORICAL

The history of the Pittsburgh Water Works dates from August, 1802, when proposals were received for the building of four public wells on Market Street and $497.95 taxes were levied for that purpose.

In 1813, George Evans served notice that he was ready to pump sufficient water by steam power to run to any part of the town, and to supply consumers at 3 cents per barrel. Again, in 1818, Messrs. Foster and Hamilton petitioned Councils for permission to supply water, but there is no record that either of these two projects materialized.

In 1824, Councils authorized the purchase of a reservoir site on Grant's Hill, and an engine house site at the foot of Cecil Alley on the Allegheny River. These sites cost $3,800.00 and $1,425.00, respectively. In December, 1826, contracts were let for a million gallon reservoir and a pumping engine. In September, 1828, these were turned over for operation; however, many imperfections developed, so that it was May, 1829, before an appreciable quantity of water was furnished. The first annual report was made in that year, and showed the water consumption to be about 4000 gallons per day.

In 1838, the purchase of a new reservoir site 160 feet above the river at Prospect and Elm Streets was authorized, and the following year construction was begun. This reservoir was at the present site of Washington Park. In 1834, the Cecil Alley pumping station was moved up the river to the corner of Etna Street and Duquesne Way.

In 1848, Councils appropriated $30,000.00 for the purpose of constructing a basin or reservoir, now known as the Bedford Reservoir, which was completed in 1850.

[1] Presented before the Central States Section meeting, November 3, 1922.

[2] Division Superintendent, Distribution Division, Bureau of Water, Pittsburgh, Pa.

In 1870, the water supply for the higher territory being inadequate, a small pump was installed at the lower basin to pump water to the Bedford basin, and at this time a sub-station was erected at 45th Street, to supply the Lawrenceville district.

In 1872, complete rebuilding operations were started, resulting generally in the plant as it exists today. Very little of the water works of fifty years ago is still in use.

The water consumption fifteen years after the first plant was placed in operation was less than 1,500,000 gallons per day; this had increased to about 14,000,000 gallons in 1872, while the cost of the plant to April, 1872 (fifty years ago) was $1,627,860.12.

The description of the water works plant, as it exists today, practically rebuilt during the past fifty years, is the object of this paper. The historical cost of the used and useful water works plant was in December, 1919, $31,739,458.00.

ORGANIZATION

The Water Works of Pittsburgh is owned and operated by the City of Pittsburgh.

The City is governed by a Council of nine members, elected at large, whose functions are legislative, and by a Mayor, also elected at large, who is the chief administrative officer. The Mayor appoints the several Directors of Departments. The Director of the Department of Public Works is the chief administrative officer in charge of the different Bureaus that construct and operate the public works of the City, among which is the Bureau of Water.

This Bureau, presided over by a Managing Engineer, who, as the title indicates, is the Manager and Chief Engineer in charge of the Water Works, is operated through four divisions in charge of three Division Superintendents and one Chief Clerk, as follows: named in the order of the progress of the water through the Water Works plant:

The Filtration Division, presided over by a Division Superintendent, who is practically the Sanitary Engineer of the Bureau, in charge of the Filtration Plant, including the Chemical and Bacteriological Laboratory.

The Mechanical Division, presided over by a Division Superintendent, who is practically the Mechanical Engineer of the Bureau, in charge of the several pumping stations and the rising mains to the reservoirs and tanks.

The Distribution Division, presided over by a Division Superintendent, who is practically the Civil Engineer of the Bureau, in charge of the Distribution System, including the distribution reservoirs, tanks, pipe lines and domestic service.

The Accounting Division, presided over by a Chief Clerk, in charge of all matters of accounting.

It will be noted that the line of demarkation of the functions of the divisions is defined by the progress of the water and is such that each Division operates as an entity, with no confusion as to duties or responsibilities.

Each Division is charged with the design, construction, operation and maintenance of its portion of the water system, and the Division Head is held strictly accountable.

The assessment and collection of water rents are not functions of the Bureau of Water. The assessment is in charge of a Board of Water Assessors of three members, appointed by and reporting to the Mayor. The collection of water rents is in charge of the City Treasurer and Collector of Delinquent Taxes, a departmental officer holding the dual position, appointed by and reporting to the Mayor.

THE DISTRIBUTION SYSTEM

The distribution system is operated through three sections, named in the order of the progress of the water: Reservoirs, Pipe Lines and Domestic Service.

The historical cost of plant operated by the Distribution Division was, in December, 1919, as follows:

Reservoir Section	$3,332,251.48
Pipe Line Section	13,545,877.19
Domestic Service Section	720,740.11
General Division Office	5,649.38
	$17,604,518.16

The distribution storage facilities consist of three large and two small reservoirs, total capacity—414.7 million gallons, also twelve tanks, total capacity—4.2 million gallons.

The pipe line system consists mainly of 764.16 miles of pipe lines, 7112 fire hydrants and 17,747 gate valves. The distribution of pipe sizes is shown by the following table.

Distribution pipe lines in service, January, 1922

SIZE	MILES	PER CENT OF TOTAL	REMARKS
inches			
½–2–3	7.47	0.97	Wrought iron
4	106.91	13.99	Cast iron
6	363.81	47.61	Cast iron
8–10	110.32	14.44	Cast iron
12–14	61.79	8.09	Cast iron
15–16–18	26.60	3.48	Cast iron
20–24	41.02	5.37	Cast iron and steel
30–36	31.62	4.14	Cast iron and steel
42–48–50	11.06	1.45	Riveted steel
60–66	3.56	0.46	Riveted steel
Total..........	764.16	100.00	

New pipe lines added in 1921 amounted to 14.5 miles; while the number of leaks per mile of pipe in 1921 was 0.33. The average water pressure at the fire hydrants is 77 pounds.

The Domestic Service Section is in charge of 94,288 service connections, 37,514 water meters, 120 troughs and fountains, and all waste water and similar inspection work.

Of the service 39.79 per cent is metered, representing practically all service connections larger than 1 inch, except automatic sprinkler service connections. The distribution of sizes of service connections and water meters is shown by the following table.

Service connections and water meters in service, January, 1922

SIZE	SERVICE CONNECTIONS	WATER METERS
inches		
⅝	79,498	25,528
¾	8,899	6,857
1	4,572	2,988
1¼–1½	102	729
2		740
3		322
4	844	279
6	356	66
8	10	2
10–12	7	3
Total.................	94,288	37,514

The population supplied by the City plant was in 1920, 547,025, while the private companies supplied 43,018 persons within the City limits.

DISTRIBUTION SYSTEM

The unusual features of the distribution scheme of the Water Works of Pittsburgh are due almost entirely to the rugged topography of the City, the outstanding features of which are many high hills, separated by deep ravines and wide rivers. There are practically no level spaces, except the narrow strips along the rivers. This topography is responsible for the nine separate water distribution systems.

In addition, there are portions of the City, somewhat recently annexed, supplied by the Pennsylvania Water Company and the South Pittsburgh Water Company, making a total of eleven distribution systems within the City limits.

Topographically, the City is separated into three parts; Central City, or Peninsular Pittsburgh, between the Allegheny and Monongahela Rivers; North Side, formerly Allegheny and Spring Garden Borough, North of the Ohio and Allegheny Rivers; and South Side, South of the Ohio and Monongahela Rivers.

Primary systems

There are two primary service systems:

Low service, with its Highland No. 2 Reservoir supplied from Brilliant Pumping Station, and its North Side Reservoir, supplied from Aspinwall Pumping Station.

Highland No. 1 service, with its Highland No. 1 Reservoir supplied from Brilliant Pumping Station.

In the following descriptions, the elevations given are referred to Sandy Hook datum, while the census of 1920 is used for population data.

The low service system supplies the manufacturing and mercantile district on both sides of the three rivers from the low river elevation of 696 to about elevation 900 feet. The average hydrant pressure is 80 pounds. The population supplied is 173,947.

Highland Reservoir No. 2, completed in 1902, capacity 112 million gallons, depth of water 30 feet, is constructed with earth embankments, puddle water-proofing, ashlar masonry slope lining and concrete bottom lining.

North Side Reservoir, completed in 1914, capacity 151 million gallons, depth of water 40 feet, is constructed with earth embankments, lined with two layers of concrete and an asphalt-burlap membrane water-proofing.

The elevation of these two reservoirs is practically the same, being 975 and 972 feet respectively.

Leading from Highland Reservoir No. 2 are two 50 inch steel mains, one paralleling the Allegheny River as a 42 inch and a 36 inch main to the Point district, and continuing parallel with the Monongahela River to 10th Street Bridge, where connection is made with the South Side mains by means of two 24 inch pipes suspended from the bridge.

The other feeder main leads directly to the Monongahela Valley, feeds the outer Avenue district, crosses under the Monongahela River as a 36 inch steel main, and forms the main feeder for the South Side.

Leading from the North Side Reservoir is one 60 inch steel main to the heart of the North Side district.

At 26th Street, a 48 inch steel main is laid in the bed of the Allegheny River, and from the Manchester Bridge two (2) 24-inch mains are suspended, connecting the systems of the North Side and Central City. These, together with the two Monongahela River crossings, make it possible to supply any portion of the Low Service system from either reservoir.

Highland No. 1 system supplies a large residential, mercantile and manufacturing district, comprising mainly East Liberty valley, Shadyside and Oakland, between approximate elevations 900 and 1000 feet. The average hydrant pressure is 60.25 pounds. The population supplied is 157,155.

Highland No. 1 Reservoir, elevation 1064 feet, completed in 1879, capacity 117 million gallons, depth of water 21 feet, is constructed with earth embankments, puddle water-proofing and ashlar masonry lining.

Leading from this reservoir are four 30 inch and one 36 inch feeders radiating to all parts of the system. The equalizing main at the reservoir is 66 inches in diameter.

Secondary systems

The three secondary systems of the Central City are known as Herron Hill, Bedford and Lincoln.

Herron Hill System supplies a residential district comprising the widely separated Herron, Squirrel, Garfield and Heberton Hills between approximate elevations 1000 and 1220 feet. The population supplied is 72,393. The supply is pumped at Herron Hill Station from Highland No. 1 system to Herron Hill Reservoir.

Herron Hill Reservoir, elevation 1259 feet completed in 1880, capacity 12 million gallons, depth of water 21 feet, is constructed with concrete lined earth embankment, relined in 1920, with a reinforced 2 inch gunite concrete lining.

Bedford system supplies a congested residential and small mercantile district adjacent to the Point Section, between approximate elevations 920 and 1030 feet. The population supplied is 22,388. The supply is from Herron Hill Station to Bedford Reservoir.

Bedford Reservoir, elevation 1094 feet, completed in 1854, relined in 1907, capacity 2.7 million gallons, is constructed with earth embankments lined with two layers of concrete and asphalt-burlap membrane water-proofing.

Lincoln system supplies a small residential section in the northeasterly portion of the City between approximate elevations of 1000 and 1250 feet. The supply is pumped at Lincoln Station from Highland No. 1 System to Lincoln Tank, a single tank at elevation 1279.5 feet. The population supplied is 5567.

Allentown system supplies a population of 53,635 in the residential hill section of the South Side, between approximate elevations 900 and 1260 feet. The supply is pumped at Mission Station from the Low Service System to Allentown Tanks.

The three Allentown Tanks, elevation 1294.5 feet, completed in 1895 and 1904, have a combined capacity of 2.5 million gallons.

Montgomery-Spring Hill and Lafayette systems supply a population of 58,375 in the residential hill section of the North Side between approximate elevations 900 and 1200 feet.

The supply is pumped at Howard Station from the Low Service System to three sets of two tanks, having a combined capacity of $1\frac{1}{4}$ million gallons.

The Montgomery and Spring Hill Tanks are at elevation 1198, while the elevation of the Lafayette Tanks is 1279.5 feet.

Tertiary system

Greentree System supplies a population of 3715 in the northerly section of the North Side above elevation 1200 feet.

The supply is pumped at Greentree Station from the Lafayette System to Greentree Tanks—two tanks at elevation 1386 feet, having a combined capacity of 828,000 gallons. The flow line of these tanks is 692 feet above the river level.

Plans are prepared for extensive changes in the North Side High Service systems, including a large reservoir at the Greentree Tank Site.

Plans are also prepared for a large reservoir in the Lincoln district to supply the Lincoln, and a portion of the Herron Hill distribution systems.

MICROFORCES: WITH REFERENCE MORE ESPECIALLY TO ORIENTATION AND CURVATURE[1]

By Frank Hannan[2]

Bacon, in one of his many happy phrases, calls attention to the necessity for investigation which has "Light," rather than "Fruit" as its end; for a clarification of principles must antedate frequently the development of practical results. In engineering, as in other sciences, the philosophic viewpoint is not without its value, even when entering the wilderness of practical performance. It no longer seems presumptuous to turn aside from the current work of the engineer, to glance, even though diffidently, into the world of molecular dimensions, when by this time most of us, in varying degree, are viewing with amazement the increasing understanding of a world still hazy, amorphous, but pregnant with unbounded possibilities.

A decade ago, the engineer might justly have received a paper on microforces with suspicion. Reference to problems of size and of orientation of molecules, and of surface curvature of aggregates of molecules, might have given rise to interest born rather of amusement than of curiosity. Increasing familiarity, however, with the macro-, or cruder, elements of engineering structures and mechanisms has brought about gradually a realization that, *for practical reasons*, we should begin to examine our working material with more delicate instruments and with an effort to pierce below the obvious in size and in structure.

Not many years have passed since the usual recourse of the engineer, in almost every branch of his activity, was to what Sir William Pope (1) has so deprecatingly styled the "rather fierce methods" of the laboratories of a former generation. Later, in his paper on "Chemistry and Life" (2) he eulogizes "newer and less violent" chemical methods, which are to yield us ultimately an

[1] Presented before the Chemical and Bacteriological Section, Detroit Convention, May 25, 1923.

[2] Chemist, Filtration Plant, Toronto, Ontario, Canada.

approximation to an understanding of the chemical processes of plant and animal life. With some exceptions, we are still prone to analyze our problems from the surface of the stream of life. In this paper, a dive below the surface is attempted. With the inexperience of the present diver, the amount of the salvage from the depths will have to depend largely upon the helping hand and mind of the reader. The plan will be to present briefly some of the familiar problems of the engineer in terms of the forces "of low potential energy," microforces, so poorly understood, yet so completely responsible for successful operations in countless cases; forces, however, the effect of which tends to become quite inappreciable when the masses acted upon, or the range of action, exceed certain small, but not clearly defined, limits.

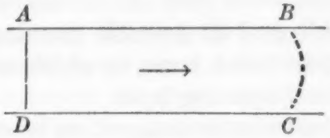
Accustomed as we are to ever-increasing scales of operation, it is far from easy to realize how completely we must shift our viewpoints and how many forces, ordinarily negligible, have to be reckoned with in the study of the microcosm. A few instances, chosen at random, from the mineral, the vegetable, and the animal kingdoms, will serve to show the significance to the engineer of microforces:

a. Strength of materials depends upon intermolecular attraction. It is, perhaps, the chief purpose of the engineer to see that his stresses do not exceed the limits thereby imposed. When we consider the wide range in properties exhibited by steels varying but slightly in chemical composition, or, again, by one and the same steel under different heat treatment, or, to take yet another example, by different concrete aggregates, the importance to the engineer of the control of intermolecular forces is obvious.

b. The root of a tree will extend as the growing point determines. The growing point is so sensitive to its environment as almost to seem possessed of intelligence. In the result, huge masses of rock may be split; walls may be overturned; sewers may become choked, or burst; all because of the path pursued by the delicate, fragile growing point in obedience to the microforces impressed upon it.

c. Consider the engineer himself. We harbor about us myriads of streptococci, staphylococci, and the rest. Sometimes we "rub them the wrong way," or, it may be, import a new strain from outside sources; to use a medical expression, "our immunity is depressed;" they turn upon us, burrow into our tissues and, unless we are successful in correcting the environment, serious, even fatal, results may follow.

To proceed with our theme, let us first, for a moment, consider the flow of water through a pipe. The well-known conditions of straight-line flow are represented graphically in the figure:



A B C D is an axial section of a pipe in which water is flowing in the direction indicated by the arrow. If we plot the velocities of the water at the various points of the cross-section *A D* as abscissae, against the points themselves as ordinates, we obtain a graph like the dotted line *B C*. But, if the water wets the inner surface of the pipe, as is, in practice, usually the case, a little consideration will make it clear that the dotted line *B C* does not completely reproduce the facts. For, in this case, the water molecules in immediate contact with the pipe must have zero velocity and the true intersections of the graph with *A B* and *D C* respectively must be at *A* and *D*. If it were possible to obtain these extensions of the graph from *B* to *A*, and from *C* to *D*, and so to magnify them that their contour could be studied, our knowledge of the processes of filtration would be very greatly extended. For it is in just such a layer that the happenings which chiefly concern us take place. Particles which cannot be enticed therein must inevitably pass through our filters at the rates of filtration usual in practice. A mental comparison between the size of the *largest* bacteria and that of the *smallest* sand grains will make this conclusion sufficiently obvious. Whenever, with lapse of time and consequent accumulation on the surface of the filtering medium, the free channels for the water become so reduced in cross-section as to approximate to bacterial dimensions, these stagnating layers have assumed a more and more formidable percentage of the remaining cross-section, and the loss of head has become uneconomical. Similarly, as every engineer knows, puddled clay, with more voids than has sand, is yet impermeable to water, even under considerable pressure.

On the other hand, should our object be, not to effect purification, but to enumerate the organisms present in a sample, we must avoid enticing the organisms into the stagnating layer of a pipette. For, once there, a bacillus will be, to all intents and purposes, lost to an

ordinary experiment. That this is no imaginary complication is clear from the experiments of Dejust, Wibaux and Dardel (3) with glass tubes; and from those of Lloyd and Frothingham (4) with table ware.

We may therefore regard as desirable knowledge which tends to elucidate the conditions which favor, or which antagonize, the entry of a particle into the stagnating layer.

It may be asked: just what is a stagnating layer? It is very much what its name implies; it is that layer of liquid at the liquid-solid interface which immediately adjoins the solid and wets it; thereby losing much of its mobility. Its thickness is not well defined, and is subject to much variation as the conditions change. Its mobility must be expected gradually to increase as we recede from the interface, merging imperceptibly into that of the bulk.

The terms orientation and curvature being somewhat unfamiliar, a short explanation may be acceptable.

Orientation is a directional constraint. It can perhaps be most readily understood by consideration of a well-known example, the magnetic needle. A steel needle, suspended by its center of gravity, and free to move in any direction, will, before magnetization, remain at rest in any position whatever, indifferently. After magnetization, it will always come to rest in one position only; namely, with its axis in the magnetic meridian, and at a definite inclination to the vertical. It is now oriented. Another well-known example of orientation is polarized light, the vibrations of which are confined to a single plane through the axis of the ray.

Curvature, though we all can recognize it, is not easily defined. It is aberrancy from the rectilinear. This fixes it at once as being a property essentially planar. For the right line, and the aberrant point, between them, determine a plane. Confining ourselves therefore, in the first instance, to planes, there is but one curve which at every point in its course, is equally aberrant from rectilinearity; namely, the circle. Any one arc of any circle of given radius will coincide exactly with any other arc of equal length upon which it may be superposed. The radius of the circle is therefore an absolute measure of curvature. The smaller the radius, the greater the curvature; and vice versa. In any curve other than a circle, curvature varies from point to point, and the curvature at any point is that of the "osculating," or most closely fitting, circle at that point. Without going into mathematical detail, we can get a notion of the

most closely fitting circle in the following way. Draw the normal to the curve at the point in question, and, taking centers at increasing distances along the normal, on the concave side, draw a series of circles touching the curve. At first, when the center is taken near the curve, the circle will lie altogether on the inside of the curve; but, as the circles get larger, they will eventually be found to lie outside; that is, between the curve and the tangent. The point on the normal at which the transition takes place from inside to outside is the center of the most closely fitting circle. The radius of this circle is the radius of curvature of the curve at the point considered. Extending now our ideas to three dimensions, suppose our point to lie on a surface. Drawing the normal to the surface, we can have an infinite number of planes through the normal, corresponding to each of which there will be a radius of curvature. Between these radii, many simple mathematical relations subsist; such, for example, as, that the plane of least curvature is at right angles to that of greatest curvature. Points on a surface at which the curvature is the same in every direction are known as umbilics.

To resume, it should be remembered that the stagnating layers or films, as they are sometimes called, are a well recognized physical phenomenon of much practical significance; as, for example, to the engineer, by reason of their high resistance to the transfer across them of heat, and, again, by the part they play in lubrication, in corrosion, etc.; to the electrician, by their disturbing influence upon potential differences, electro-deposits, resistances, etc.; to the chemist, as the seat of inter-reaction between phases, especially of heterogeneous catalysis, etc.; to the student of living matter, as the seat of all metabolic and of most other vital activities. They are visible under the microscope in the capillaries, as "Poiseuille's layer" in which the leucocytes move sluggishly along, whilst the erythrocytes keep clear of it.

As an aid towards a definite mental picture of these layers, it will help, briefly to review some of our present knowledge of the solid state. In a crystalline solid, which some assume to be the only true solid, X-ray examination has revealed the fact that the spacing of the atoms is absolutely regular. It has been measured for many substances to an accuracy of 1×10^{-10} cm. This will be referred to later. The engineer, who knows, for example, the time and trouble which would be needed to lay, say, a million bricks with a tolerance of, say, $\frac{1}{16}$ inch, can realize better than most the marvel of speed and

precision, by which within a few seconds billions of molecules may be assembled into a crystal, each exactly oriented, and not one ten-billionth of a centimeter out of place. It is usually assumed that in the solid state the individual molecules have lost all freedom of motion of translation and of rotation with respect to one another, retaining only their vibrational freedom. This is probably strictly true of single crystals, each of which can, indeed, be looked upon as one large molecule. Such facts, in other cases, as the migration of ions in glass, and the inter-diffusion of solid metals, tend to conflict with the assumption.

In the fluid states, molecules are held to enjoy more or less of both rotational and translational freedom, which, in the gaseous state (monatomic gases excepted) is nearly complete. Our knowledge of the molecular freedom of liquids is still very imperfect.

With respect to water, uncertainty still prevails as to what the molecule really is. The weight of the evidence, at the moment, seems to favor "dihydrol," $2H_2O$, as the chief constituent of liquid water.

It seems to admit of little doubt that the stagnating layers must owe their remarkable properties to a greater or less degree of orientation, or loss of freedom. That layer of liquid molecules in immediate contact with the solid surface is generally regarded as having lost its fluidity. What, then, are we to say of the layer next to it? It is in contact with what is virtually a solid surface of a different kind. Each layer in turn will present a new problem. As Hardy (5) so well describes it: "as we proceed along the normal to the interface, the heterogeneity is very marked." It is easy to see that the rate at which the bulk of the water in the pipe is travelling will have a good deal of influence. This factor alone would account for some of the observed differences between slow sand and rapid sand filtration. Again, the marked heterogeneity goes far towards explaining the many-sidedness of the phenomena of colloidal sols and gels, where each "primary" particle is, presumably, surrounded by a series of layers of progressively decreasing orientation. The sol-gel transition would naturally result when orientation has so far progressed that layers sufficiently oriented of neighboring particles are in contact sufficiently closely; and vice versa. Clearly, too, the viscosity must alter continuously as orientation progresses.

Orientation is not limited to the liquid-solid interface. It can hardly be doubted that liquid-liquid, gas-liquid, and gas-solid inter-

faces are subject to the same phenomenon. The spreading of films on liquid surfaces has received considerable attention; two recent articles dealing therewith will be here referred to, both of which will well repay careful consideration; one, by Professor Edser (6), in the Fourth Report on Colloid Chemistry; the other by Drs. Harkins and Feldmann (7) in the December, 1922, issue of the Journal of the American Chemical Society. It is true that Professor Edser frankly proclaims himself "from Missouri" regarding orientations of water molecules at the air-water interface; also that Drs. Harkins and Feldmann, while presenting compelling evidence of the necessity for orientation, refrain from applying it to the water molecule.

The importance of the air-water interface to the waterworks engineer makes it worth while to recapitulate briefly from Drs. Harkins and Feldmann. It is pointed out that the electro-magnetic forces round a molecule are, in general, different at different parts of the molecule. The asymmetry of the water molecule is well known. The powerful attraction which water in bulk possesses for certain polar groups in the molecule, of which, *the OH group is among the most prominent,* is emphasized. *The necessary consequence is the orientation of molecules containing polar groups, when applied at the air-water interface;* the polar group seeking contact with the water, and the non-polar, or weakly polar, being directed away from the water. Now, whether the molecule of liquid water be H_2O, $2(H_2O)$, or $3(H_2O)$, the fact of its containing the OH group is one which not many of us will be prepared to dispute. But "what is sauce for the goose must be sauce for the gander;" if the rule holds, that molecules with the OH group, applied at the air-water interface, must orient themselves with the OH group towards the water, then the water molecule itself can be no exception.

Orientation will not be confined to a single layer of molecules at the interface; it will extend down for thousands of layers, the distance depending upon (*a*) the range of the attractive force between the OH group and the bulk of the water, and (*b*) the effect of the orientation itself in promoting further orientation. Some few data are available upon the rate at which such layers begin to form at a fresh interface. Freundlich gives data of Dupre, Rayleigh, Milner, and of his own; the solutions examined being sodium oleate, saponin, and heptylic acid. The surface tension of a fresh surface of sodium oleate is nearly equal to that of pure water (about 73 dyne/cm.); within a minute or two it has fallen to about 26 dyne/cm., or not much over

one-third of its original value. It is noteworthy that the surface tension of water itself and of most aqueous solutions changes either not at all or very slightly by the orientation of the surface. This is one excellent reason for the difficulty in accepting orientation. Freundlich in his discussion of "dynamic" (i.e., fresh surface) surface tension, remarks upon the great difficulty of obtaining concordant results; a perfectly natural result when we consider the rate at which orientation sets up.

Orientation can be expected to proceed from the surface inwards more and more slowly; there are as yet no data available as to how far it can go, or as to its rate of progress along the normal. Some little light is thrown on this by the Liebreich zone, which will be soon described.

An oriented layer already formed is seen to spread with avidity at an apparently definite rate, over a fresh surface adjoining. Professor Edser quotes Osborne Reynolds as stating that "under favorable circumstances a very narrow ridge can be seen, separating the water contaminated with grease from the pure water beyond this." Just such a "very narrow ridge" seems always to demarcate the advancing edge of the oriented layer when conditions are not too turbulent. On the rivers of Ireland, the fishermen and boatmen call it the "hair line," and have some quaint traditions about it. No doubt the frequenters of the water surface on this continent are equally familiar with it; they may have another name for it, though hardly a more apt one.

A few of the more important phenomena which may with little hesitation be ascribed chiefly to orientation are: Ageing; hysteresis; crystallization; coagulation; precipitation; contact catalysis.

As evidencing the oriented water layer at the air-water interface, in addition to the "hair line" phenomena already described, there is also the Liebreich zone. This phenomenon was first brought to the attention of the present writer by an original observation of R. E. Thompson. When a recently agitated turbid suspension is set to stand, within a short time an extremely thin, but almost perfectly clear, layer may be observed just beneath the surface. This tendency of the oriented layer to crowd out the suspended particles is in remarkable agreement with the observed fact that ice, in freezing, pushes out the impurities (8). The Liebreich zone is distinguishable by its appearance from ordinary sedimentation. It is greatly retarded by temperature increase, which favors sedimentation (but

antagonizes orientation). It is also highly sensitive to direct sunlight. At the usual laboratory temperatures, it is usually just visible in five to ten minutes, and seems to attain its full depth within fifteen or thirty minutes. Standing for days seems to change it little or nothing. A few minutes in direct sunlight may almost obliterate it; but it reappears about as fast in diffuse daylight. It has recently come to the notice of the writer that Liebreich was the discoverer of this phenomenon, to which he gave the name of "the dead space of chemical reactions" which agrees with the interpretation which he, in the light of the knowledge then existing, put upon it. It is fairer to Liebreich, less cumbersome, and more appropriate, to call it simply the Liebreich zone. It is a consequence, but not a necessary consequence, of orientation. Its study will certainly help to win some knowledge regarding orientation.

It is a rather significant fact that Perrin's observations on the vertical distribution of colloidal particles, around the interpretation of which some controversy has of late been centered, were, of necessity, confined to layers subject to orientation. This may help to account for the failure of Perrin's law to apply to the bulk of a hydrosol.

To recapitulate: in water, the peripheral layers assume rapidly more or less orientation. Given quiescence, orientation will, presumably, be progressive (ageing); data of an exact nature are lacking. Agitation and heat will generally antagonize orientation; some side effects of agitation may, however, as we shall see later, have a directly contrary result.

Orientation does not stand alone. It is closely bound up with curvature, the effect of which is often too readily assumed to be inappreciable. Curvature may be regarded as the quality of a surface, as distinguished from mere quantity, or total superficial area. Professor Oden (9), from whose acute observation little of importance seems to escape, refers to its possible significance. Reboul and Luce (10) give mathematical proofs that chemical activity at a surface will increase with the curvature. They, and Luce (11) cite numerous examples. But it is hardly too much to assert that in the vast majority of interfacial phenomena, the influence of curvature may be distinctly traced. It is true that it is not usually referred to specifically as such; but as "degree of dispersion," "shape of the vessel," etc.

Reference has already been made to the assembling of the crystal, and to the wonderful forces, taken to be electro-magnetic, which turn out the crystal faces exactly plane. It is a remarkable fact that the most striking difference between crystalloids, on the one hand, and colloids, on the other, is this very absence of curvature. And, hand in hand with absence of curvature, is found inability, or feeble ability, to function as a catalyst. Increased curvature ("finer division") almost always means increased catalytic power, until we begin to approach molecular dimensions. A good example is the well-known series: platinum metal, platinum sponge, platinum black, colloidal platinum; in which the catalytic power is found in every case to be increasing up to platinum black; colloidal platinum shows for some reactions, a further increase of power, for others, a falling off. A somewhat similar picture is presented by nickel. Returning for a moment to the analogy between molecules and bricks, and remembering that, the smaller the radius of an arch, the wider the opening between bricks at their outer ends, this behavior is just what one would expect, if increased catalytic power follows increased facility of surface penetration. Also, a falling off in catalytic power is to be expected when the angle between "bricks" is so great that molecules entering can no longer be securely gripped.

Another example, not without its lesson for water works men, is the following. Bancroft (12), referring to mordanting with alumina, says: "the substance adsorbed and held firmly is colloidal alumina. Coagulated alumina may be absorbed to some extent, but it easily rubs off the material." By colloidal alumina is here understood the hydrosol. Water filtration is quite closely analogous to dyeing. Complete purification of the water, the main object sought, corresponds to absolute exhaustion of the dye-bath. The fabric in our case is the filter-bed; and fastness to washing is, for us, undesirable. In these two short sentences of Bancroft may be discerned a complete vindication of the empirically developed mechanical filtration process. The preliminary intimate mixture of alum and water yields colloidal (i.e., hydrosol) alumina which adsorbs, or is adsorbed by, the impurities to be removed; a very rapid process. Coagulation follows; the alumina is left upon the sand in that condition in which it "rubs off easily."

Yet another "degree of dispersion" example is lithopone manufacture. It has not been found possible, or, perhaps it would be more correct to say, prior to Dr. Plauson's development of his

colloidal mill, it had not been possible to prepare a satisfactory pigment from massive zinc sulphide and barium sulphate, however finely ground and intimately mixed. At first sight this seems rather hard to understand. A reasonable explanation would appear to be that by the simultaneous precipitation in sufficiently dilute solution, opportunity is afforded for the elementary barium sulphate particles to collide with and adsorb zinc sulphide particles before, by colliding with one another, more coarsely crystalline aggregates have time to form, with greatly reduced adsorptive capacity for zinc sulphide, although still capable of readily adsorbing dyestuffs. Compare this behavior with the results achieved by Clark (13) in his new filtration process. Massive alumina is found to adsorb color with great readiness; but bacteria, less readily. Gore (14) observes: "the act of catching impurities by the alum is the fundamental point of coagulation, and must not be confounded with the precipitation which follows it. . . . . Unless the impurity is caught before filtration, very little prospect remains of its being caught at all." It is not to be doubted that bacteria were the impurities which Gore had in mind, and Clark's results, while not bearing him out to the letter, yet show that, so far as bacteria are concerned, Gore's statement really conveys the gist of the matter. An ingenious plan, in principle akin to Clark's, was developed by Maddock (15) at Oshkosh. His results should throw further light on this problem. It is desirable we should know to what extent the hydrosol form of alumina is indispensable for effective purification. Whenever it can safely be dispensed with, the way to marked economies in coagulation is clear.

We have seen that water surfaces are layers of oriented molecules, probably thousands deep. When the water surface takes a curved form, the electro-magnetic field thereby developed is such that the following laws obtain: (*a*) convex attracts convex; (*b*) concave attracts concave, and (*c*) convex and concave are mutually repellent. Not only so, but the degree of attraction or repulsion is seen to vary with the curvature. Simple experiments with bubbles and floating droplets may be used to verify these laws. For example, illustrating (*b*), the bubbles formed in tap-water in a clean cylindrical glass vessel wander at once, as is well known, to the concave meniscus. It is not so well known, nor has the present writer seen it recorded, that when the cylinder is inclined from the vertical, so that the curvature of the meniscus is no longer the same at every point, the bubbles at once

seek the point of maximum curvature, being evidently powerfully attracted. Bubbles will detect irregularities in the shape of a vessel. An illustration of (*c*) is got whenever, owing either to a grease spot, or to filling above the brim, a bubble comes into the neighborhood of a convex meniscus. Floating droplets can be used to illustrate (*a*): these, besides being unstable, are hard to produce upon water. Following a suggestion of R. E. Thompson, based upon his personal observations, alcohol of 80 per cent was used, and comparatively stable droplets obtained, whose behavior, apart from the greater stability, closely paralleled that of the water droplets.

An explanation of the fields of force set up is given by a consideration of the crystal structure. An oriented film partakes largely of the nature of a crystal. We have referred to the intensity and precision of the forces which marshal the molecules to form plane surfaces, exact to the ten-billionth of a centimeter. Similar forces, if less intense, and less precise, give the oriented film its quasi-crystalline structure. To bend the film, these forces must be overcome to a certain extent, and a field set up which tends to restore the plane surface.

The spreading of the oriented film over an adjoining raw surface has been referred to. Ordinary plane water surfaces were in question. The film will, however, spread upon a raw convex surface. A stream from the jet of a wash-bottle, directed into a surface carrying small floating particles, may, if its velocity be not too high, become coated with the film, as can be seen by the presence of the particles. R. E. Thompson has succeeded in showing that when conditions are suitably chosen, the rush of the oriented film to cover a raw concave surface of small radius (say, 2 to 3 mm.), may be quite violent.

Emulsions are a field in which curvature effects may perhaps be studied with profit. It seems reasonable to expect that for given conditions, there will necessarily be, for any given phase-pair, an *equilibrium interfacial curvature*. Clayton (16) gives a summary of the very considerable progress which has been made towards establishing this important principle, which would explain the limitation of growth and the shape assumed by living matter, and to a derangement of which could be ascribed such phenomena as the giant cells of malignant growths, etc.

Algal growths have been noted to exhibit very marked preferences with respect to curvature, when grown in glass bottles.

At the air-water interface, as we have seen, the less reactive ends of the molecules are directed towards the air and away from the water. That this arrangement is not particularly favorable for inter-reaction with the gaseous phase is but to be expected; such is found to be the case. We can improve matters in this respect by making the water surface convex; the most efficient artificial aerators adopt this principle for the most part. Nature does the same in raindrops, waves, waterfalls, etc.

Bubbles, when below the water surface, are concavities of the water, in which the less reactive molecule-ends are directed towards the gas phase and packed more closely together than at a plane surface. Reaction between the phases should be more difficult than at the surface. For the most part, this, too, is found to be the case. But bubbles possess a strong electro-magnetic field by reason of the curved film. The more reactive ends of the molecules are directed into the water, and somewhat pried apart, as it were. This has been indicated as the kind of structure probable for catalysts; and it has been found that small bubbles exercise a very considerable catalytic or quasi-catalytic action, which has also to be taken into reckoning.

The water molecules at any water interface have been pictured as marshalled in layers, each layer differing probably to some slight extent from its neighbors. In the companion phase, if a fluid, whether gas or liquid, a somewhat similar state of affairs is probable; if a solid, it is probable that minute stresses replace actual orientations. For brevity the whole can be referred to as an *interfacial system*. One main object of the present paper is to advocate the advisability of thinking in terms of interfacial systems rather than of interfaces. The water in the water side of an interfacial system is oriented, or, as it were, polarized; causing it to be not, as Liebreich implied, less reactive, but often very much more reactive. This effect, as is natural, is greatly accentuated at the *intersections of interfacial systems*, where the electro-magnetic fields are probably the strongest.

In these intersections the water molecules are, as it were, doubly polarized, and possess, especially at the solid-liquid-gas intersection, the "water-line," or its equivalent, a reactivity which is most remarkable. Even the tyro geologist, as is the writer, cannot fail to be struck by the surprising metamorphic developments which percolating water is able to effect in fissures and crevices. The

weathering of the most resistant rocks to clay seems to be an essentially tri-phase process, and to cease as we get below the water table. A single night's dew will form a bright yellow coating on a clean steel rail. The fertility of the soil depends upon its tri-phasic condition; water-logged soil is unproductive. Whether water-logged or not, the soil is just one endless succession of interfacial intersections; yet, in this respect, it is a comparatively simple system alongside even one single cell of living matter. That orientation and curvature play a considerable part in vital processes is to be expected.

The writer, with the wise adage of Horace in his mind, "Ne sutor ultra etc.," had intended to leave the question of the application of these principles altogether to those better qualified by experience than he is. He claims no exemption from the common foible of imagining that his views are capable of successful commercial development; but it has not fallen within his province to attempt the requisite experimental proofs. It has been urged upon him that the paper would be more acceptable with some little indication of its possibilities of helpfulness.

This has already been done to some extent. It would be a matter of subsidiary consequence that water is not homogeneous, if the different portions reacted alike. But they do not. The polarized surface layer antagonizes exchange with the gaseous phase, being, in this respect, one of nature's innumerable buffer systems. For the most effective aeration, we must provide for continuous renewal of the fresh surface. Also, the more convex the water surface, the more effective the aeration. All reported observations, so far as the writer is aware, confirm these deductions. Again, bubbles, and, especially, minute bubbles, are surrounded by an electro-magnetic field, which strongly attracts many colloids (a well-known example being albumen, which concentrates in froth). They become attached with readiness to most forms of suspended matter. In a word, they serve as excellent coagulation nuclei.

As an example of a sphere in which the principles apply, consider the activated sludge process. In the diffused air system, the coagulating activity of the small bubbles more than compensates for their comparative aerating inefficiency qua bubbles; they have, as agitation agents, causing surface renewal, much aeration value. In the bio-aeration system, the paddle wheels supply the bubbles, and the long channels, traversed at from one to two feet per second, with more or less frequent return bends, are relied upon for the aeration.

With one more example the paper will conclude. Agitation, and, particularly, vigorous agitation, of moderate duration, is frequently found to favor to a marked degree the coagulation process. It is natural to assume that the bubbles contribute largely towards this result.

SUMMARY

1. Peripheral layers of quiescent water are not identical in all their physical properties with the bulk.
2. Orientation is offered as being, in the present state of our knowledge, the most probable explanation.
3. Differentiation is a rapid process. In diffused light, at ordinary temperatures, the Liebreich zone is discernible within five to ten minutes.
4. Tangential spreading of the differentiated layers over fresh surfaces adjoining occurs actively.
5. The effect of curvature at an interface is not always inappreciable.
6. The principle of *equilibrium interfacial curvature* is suggested.
7. Attention is directed to *interfacial systems* and to their *intersections.*
8. A few simple illustrations are provided.

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Mr. Abel Wolman's share in the production of this paper is so great that, by every title, he should rank as joint author. Originally intended as a continuation to joint papers, pressure of work prevented him from giving as full a measure of attention as he desired; his help and encouragement have been freely drawn upon and unstintedly given; but for him the paper could not have been produced. Mr. R. E. Thompson's invaluable observations have been already, in part, referred to. On several crucial points they proved decisive. The writer has much pleasure in acknowledging his obligation. Thanks are due to Mr. N. J. Howard, bacteriologist in charge, and to the writer's colleagues for their helpful attitude, assistance and advice. Particular thanks are also due to Mr. A. U. Sanderson, the superintendent, for facilities freely extended. Valuable help has been received from the filter operators, whose observations, notably those of Mr. Harvey, have enabled important conclusions to be confirmed. Mr. A. L. Fales is thanked for his great kindness in

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ANAEROBIC, LACTOSE-FERMENTING SPORE-BEARERS IN THE CITY OF MINNEAPOLIS WATER SUPPLY[1]

By Frank Raab[2]

Bacteriologists, engaged in water laboratories in or about the City of Minneapolis, encounter almost daily a lactose-fermenting organism which steadily resists isolation and indentification by the usual laboratory methods. The fermentation is generally dismissed with the remark: "It's probably B. Welchii." Fermentation usually begins within thirty-six hours, though at times it may be observed within twenty-four hours after the water has been introduced into the lactose broth. Gas formation is vigorous, abundant and stormy. In the early stages very little if any turbidity is produced.

Out of 14,225 lactose broth tubes inoculated with 10 ml. of purified water in the bacteriological laboratory of the plant during the past two and one-half years, 1092 were presumptives, that is they developed gas within 48 hours. Out of this number, 65 were confirmed as belonging to the B. coli group. This means that 94 per cent of the presumptives could not be confirmed. From November 15 to December 15, 1922, 171 out of 480 lactose broth tubes developed gas. Only 2 out of these 171 tubes were confirmed as members of the B. coli group. During the two and one-half years preceding 1920, the Division of Sanitation of the Minnesota State Board of Health collected 126 bacteriological samples of the Minneapolis water supply. Out of these 126 samples, 90 developed gas in 100 ml. amounts. Ten out of these 90 presumptives were confirmed as members of the B. coli group. A few of these presumptives were due to aerobic spore-bearers, but these appeared so rarely that they need not be considered here.

For a time it was believed that this organism and B. subtilis grew in symbiosis; the latter, consuming the oxygen, makes possible the growth and reproduction of the anaerobe. However, this opinion

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was not sustained because occasionally pure cultures were met with in lactose broth tubes which had been inoculated with purified water. No definite conclusion has been reached as to what makes possible the growth of these bacteria under the above-mentioned conditions. It may be that large numbers of these organisms are present in the water at the time the broth is inoculated; and further, that the broth was freshly sterilized and was thus free from dissolved oxygen, a condition which favored and promoted their growth.

Special Report No. 29 of the Medical Research Committee of England and Bulletin 62 by Prof. Max Levine of the Iowa State College, review the literature and the work done on anaerobic, lactose-fermenting, spore-bearers; but these two bulletins do not list an organism the sugar reactions of which correspond with those of the bacillus isolated in this laboratory.

In the course of the past five years repeated attempts were made to isolate and identify the causative organism; but every effort to secure a pure culture failed. During the past year another attempt was made in the laboratory of the plant and the following method for securing pure cultures was devised.

MEDIA USED

Digestive Ferments Company's dehydrated lactose broth was used for all routine bacteriological work. The special broth used was made from Parke-Davis' meat extract and bacteriologic peptone with 1 per cent of the various sugars added. The solid media used were Digestive Ferments Company's dehydrated nutrient agar and nutrient gelatin, to each of which 0.5 per cent of dextrose was added. The sugars used were Merck's and Pfandstiehl's C. P. products. The pH was determined by Medalia's method.

METHOD OF ISOLATION

A drop or less of the lactose broth, in which the fermentation is in progress, is introduced into a tube containing 25 ml. of nutrient agar to which 0.5 per cent of dextrose has been added. The agar should have a pH of 7.0 to 7.5 and it should be freshly prepared, sterilized and cooled to 45°C. After the inoculation this agar tube is incubated at 37°C. until small disc-shaped gas bubbles appear. This requires about twenty-four hours. Next the tube is broken and the agar

removed to a sterile Petri dish. The inside of the gas bubbles is carefully scraped with a platinum loop and the contents of the loop introduced into tubes of liquefied nutrient gelatin which contains 0.5 per cent of dextrose, and which has a pH of 6.0 to 6.5. These tubes are then incubated at 20°C. for a week or ten days after which time small white colonies may be observed. In the course of several weeks these colonies will become spherical in shape and have a purple or brown tinge. This appearance is characteristic in dextrose gelatin with a pH of 6.0 to 6.5. If the scrapings from the gas bubbles are introduced into a 0.5 per cent dextrose gelatin with a pH of 7.5 to 8.0, the growth of the colonies will be very irregular, and frequently show finger-like projections with clubbed ends. Very scant growth takes place in sugar-free media.

The agar tubes into which the first inoculations were made must be removed to room temperature as soon as the first gas bubbles appear. If this is not done the agar is so badly broken by the gas production that the selection of a pure colony becomes difficult. No visible colony or growth will appear in the agar tube at the time when the first gas bubbles are scraped with the platinum loop. If colonies appear, they are to be carefully avoided, because these are not the organism that is sought. After the agar tube has been left at room temperature for a week or two, great numbers of very small colonies may be observed. These small colonies are also the bacillus in question.

These bacteria rarely set up fermentation if introduced into the broth in small numbers—say, a platinum loop-full. If 1 ml. or more is used in the inoculation, gas develops within fifteen to eighteen hours. When a test of their fermenting power is desired it is best to use whole colonies picked from dextrose gelatin tubes. After inoculation the broth tube is provided with a float of sterile paraffine oil $\frac{3}{4}$ inch deep, and then incubated at 37°C.

Freshly prepared and sterilized media are most productive of growth. Repeated attempts to grow this organism on the surface of media, under anaerobic conditions, have failed.

OBSERVATIONS

The organism is a long, slender bacillus easily twice the length of B. coli. It is Gram negative and stains readily by that method. This stain demonstrates terminal spores which are always Gram

positive. It is actively motile in young dextrose cultures. The cultures have a marked butyric acid odor. They do not liquefy gelatin. They ferment lactose, dextrose, maltose, saccharose, mannite, dulcite, raffinose, inulin, salicin, starch, galactose, levulose and xylose. Glycine and lactose bile are not fermented. The dulcite fermentations, with two exceptions, were not so profuse as those of the other sugars, only 10 or 15 per cent of gas having developed.

No peptonizing action was observed with egg albumen, Loeffler's serum, milk or coagulated blood.

Sugar broths, in which the fermentation has gone to completion, reach a pH of 4.6. Cultures were found of which 10 ml. required 33 ml. of N/50 sodium carbonate solution before a permanent pink with phenolphthalein resulted. This is equal to an acidity of 3300 p.p.m. in terms of calcium carbonate.

The thermal death point of this bacillus was found to be between twenty and twenty-five minutes at 85°C. One ml. of a broth culture, mixed with 250 ml. of sterile water, resisted the action of 25 p.p.m. of chlorine for twenty hours without destruction. This means that the elimination of this bacillus by chlorination is out of the question.

A rabbit inoculated intraperitoneally with great numbers of this organism from broth and from gelatin cultures, and also fed with large numbers of them in milk, showed no ill effects.

CONCLUSION

The records quoted from the Division of Sanitation of the Minnesota State Board of Health and also those available here at the Filtration Plant establish the fact that more than 90 per cent of the presumptives obtained in the routine work of this laboratory are not due to members of the B. coli group. The gas production is, in the great majority of cases, due to an anaerobe that is not B. Welchii.

It is a debatable question whether one is justified in continuing to disregard the presence of all anaerobes in public water supplies. May not the steadily increasing stream pollution sooner or later compel the determination of the number of anaerobes as well as the species before a water supply may be certified as safe for consumption?

With the kind permission of Prof. Max Levine, the table which he quotes on page 93 of Bulletin 62 is repeated here with the addition

of the bacillus found in the Minneapolis water supply. In his bulletin Professor Levine uses the term clostridium, a name used by Trécul and others to designate similar organisms.

SPECIES	GLUCOSE	LEVULOSE	GALACTOSE	MALTOSE	LACTOSE	SACCHAROSE	MANNIT	GLYCINE GLYCEROL	DULCIT	SALICIN	STARCH	INULIN	RAFFINOSE	XYLOSE	LACTOSE BILE
Cl. welchii	+	+	+	+	+	+	−	±	−	−	+	±			
Cl. oedematis	+	+	+	+	+	−	−	−	−	+		−			
Cl. chauvoei	+	+	+	+	+	+	−	−	−	−		−			
Cl. aerofetidum	+	+	+	+	+	−	−	−	−	+	−	−			
C. butyricum	+			+	+	+	−	−	−	−	+	−			
Cl. multi-fermentans	+			+	+	+	−	+	−	+	+	+			
Cl. tertium	+	+	+	+	+	+	+	−	−	+	+	−			
Cl. sphenoides	+	+	+	+	+	±	±	−	−	+	±	−			
Organism isolated at Minneapolis, Minn	+	+	+	+	+	+	+	−	+	+	+	+	+	+	−

The writer takes this occasion to express his gratitude for kindly suggestions to the following: Lewis I. Birdsall, formerly Superintendent of Filtration, Minneapolis, Minn.; A. F. Mellen, Assistant Superintendent of Filtration, Minneapolis, Minn.; A. C. Janzig, Assistant Chemist and Bacteriologist, Filtration Plant, Minneapolis, Minn., and H. A. Whittaker, Director of the Division of Sanitation, Minnesota State Board of Health.

RECENT WATER DEVELOPMENTS AT MEMPHIS[1]

By James R. McClintock[2]

In March, 1922, the writer's firm submitted a report on the Water Supply of Memphis following a detailed investigation of the local water problem.

The existing water works have been well described by Messrs. J. N. Chester and D. E. Davis in a paper read before the Central States Section in 1920 and published in the Journal, 1921, page 377.

The principal recommendations and conclusions of the report were as follows:

RECOMMENDED PROGRAM FOR NEW SUPPLY WORKS

1. It is entirely practicable to develop a well water supply at Memphis of 75 million gallons daily or more, and there is no probability of a well-designed and adequately developed artesian supply failing to meet all municipal and industrial needs during the next thirty years.

2. The artesian water is naturally excellent in quality, being clear, cool, soft and practically free from organic matter and bacteria. This ground water, however, contains considerable free carbonic acid, the amount ranging from 90 to 130 parts per million, which makes it highly corrosive of cast iron pipe.

3. The iron content of the Memphis wells varies from about 0.2 parts per million to a maximum of 6 parts per million and the high carbonic acid causes substantial amounts of iron to be dissolved as the water flows through the iron pipe system. When dissolved iron is present in quantities greater than about 0.4 parts per million it causes unsightly stains upon plumbing fixtures, kitchen utensils, and particularly white goods in the laundry. The removal of iron and carbonic acid is therefore an essential feature for a satisfactory future well supply.

[1] Presented before the Detroit Convention, May 23, 1923.

[2] Of Fuller and McClintock, Engineers, New York and Kansas City.

4. It was recommended that the Auction Avenue development be abandoned as soon as new supply works could be put in service. Most of the present wells are of such age and condition as to be of doubtful serviceability and are potentially subject to pollution. The fine sands in this vicinity preclude large yields of water being economically secured and there is grave doubt as to the continued integrity of the main tunnel and more particularly the timber lined drifts connecting with the wells.

It was also deemed advisable to abandon the Central Avenue plant as soon as practicable, because it is uneconomical to operate and the site is not a good one for the further development of wells because of the distance from the ground surface to the artesian water plane.

The fourteen segregated wells are expensive to operate regularly and at times they discharge troublesome quantities of sand into the pipe system. On starting up these wells, after a shut down, objectionable amounts of rust are delivered into the mains. Some of them should prove serviceable for eight or ten years for emergency use during periods of high consumption, and their continued use as a reserve is perhaps advisable.

5. The Mississippi River has been frequently suggested as a source of water supply for Memphis and it is perfectly feasible to obtain a satisfactory filtered water supply from the river as is done at St. Louis and New Orleans. Such a supply would be much harder than the artesian water and also noticeably warmer in summer, although free from iron and excessive free carbonic acid. It would be cheaper to treat the artesian supply by aeration and filtration to remove iron and carbonic acid than to remove the sediment and bacteria from the river water.

A satisfactory intake in the Mississippi River would be relatively difficult and expensive to obtain at Memphis owing to the absence of rock bottom and the shifting character of the river channel.

The investment for a river supply would be nearly twice that necessary for a complete, first class, modern, artesian water development of equal capacity and the total annual costs would be largely in excess of the corresponding annual costs for a well water supply. It was therefore recommended that the Mississippi River be dismissed from consideration as a source of supply.

6. The estimated future population and rates of water consumption are shown in table 1. The probable increase in population

has been judged by the past growth of Memphis and compared with the earlier growth of similar cities. The assumed growth for Memphis is similar to that enjoyed by Cincinnati for several decades and a little higher than the growth of Louisville and New Orleans. It is not so rapid, however, as has occurred in Indianapolis, Kansas City and St. Louis.

TABLE 1

Estimated future rates of water consumption in Memphis

Estimated total rates of consumption—million gallons per day

YEAR	ESTIMATED POPULATION	AVERAGE DAILY CONSUMPTION GALLONS PER CAPITA	AVERAGE DAY	MAXIMUM DAY	MAXIMUM HOUR	MAXIMUM FIRE DRAFT	MAXIMUM DAY INCLUDING FIRE
1920	162,351	80	13.0	19.5	27.3	16.0	35.5
1925	181,000	84	15.2	22.8	32.0	16.7	39.5
1930	203,000	88	17.8	26.7	37.4	17.5	44.2
1935	225,000	92	20.7	31.0	43.5	18.2	49.2
1940	249,000	96	23.9	35.8	50.2	19.0	54.8
1945	273,000	100	27.3	41.0	57.4	19.7	60.7
1950	299,000	104	31.1	46.6	65.4	20.5	67.1

Note: Rate for maximum day assumed as 150 per cent of average daily rate. Rate for maximum hour assumed as 210 per cent of average daily rate.

TABLE 2

Capacity of supply works required to serve Western and Eastern Districts in million gallons daily

YEAR	LOW LIFT CAPACITY WESTERN DISTRICT	REQUIRED EASTERN DISTRICT	HIGH SERVICE WESTERN DISTRICT	CAPACITY REQUIRED EASTERN DISTRICT
1920	14.4	5.1	30.4	12.1
1925	15.9	6.9	32.6	13.9
1930	17.4	9.3	34.9	16.3
1935	19.2	11.8	37.4	18.8
1940	21.0	14.8	40.0	21.8
1945	22.9	18.1	42.6	25.1
1950	25.1	21.5	45.6	28.5

The water consumption estimates were based on the actual per capita consumption at Memphis, but for the future have been increased somewhat, as such a tendency to increase throughout a period of years is generally noted in most cities, notwithstanding all attempts to curtail waste.

7. The City may be arbitrarily divided into two areas designated the Eastern and Western Districts, respectively. The capacities required for the supply of the Eastern and Western districts are indicated in table 2 for different periods in the future. The low lift items refer to the capacity of wells and treatment works required, and the high lift capacity to maximum pumpages into the distribution system to be expected.

8. The plot of land in the northwest portion of the City, already owned by the Water Department, known as the Dunlap Street site is favorably situated for a new well water development. This site is adjacent to the North Parkway, which is an excellent location for wells, and it is also reasonably near to the more densely built up western portion of the City where the heaviest water consumption occurs.

After careful study of other well projects it was determined that the most economical plan would be to develop works at Dunlap Street of sufficient capacity to provide for the full draft in the Western District for a period of thirty years or more. Such a plant would then have sufficient capacity to supply the entire city for a period of eight or ten years.

Before the capacity of the Dunlap Street station is exceeded by the increasing consumption in the Western District, a new eastern station should be constructed at some location where the length of connecting lines to the distribution system will not be excessive, and a suitable area for sinking wells can be obtained, at which the depth from the surface to the artesian water plane is not too great for economical operation.

9. The new works should comprise a modern, steam-operated, high lift pumping station; a covered reservoir to equalize peak rates of water consumption and furnish a reserve for fire purposes; suitable aerating arrangements and filters for removing free carbonic acid and iron; and a new system of wells extending eastward along North Parkway for supplying this station through a suitable collecting conduit. Discharge mains should be installed to deliver the water into the present distribution system.

10. The free carbonic acid content is greatly reduced by the air lift method of pumping water from the wells, about 80 per cent being removed. This was conclusively proved by experiment and by observation of air lift installations in various parts of the City. To insure against corrosion in street mains and consequent increase

in iron content, the carbonic acid should be reduced to 10 parts or less, which result can best be obtained by suitable aeration through coke beds together with the application of small quantities of lime.

11. The iron can be readily and completely removed by passing the water through rapid sand filters at normal rates for mechanical filters and can be completely removed from fully aerated water only by such means.

12. The advantages of a highly polished, sparkling product from the city water works fully warrant the relatively small expense of removing the iron and carbonic acid. By carrying out these recommendations the citizens will obtain freedom from iron stains and the unusually high corrosive action of the artesian water. Memphis will then have a city water equaled by few cities of like size in the world and surpassed by none.

13. The air lift is the best method for raising water from wells and delivering it to the treatment works at Dunlap Street. Electrically operated deep well pumps would be somewhat more expensive and do not show the advantage which the air lift possesses in removing the larger part of the free carbonic acid.

As a result of the report the City decided to construct new water supply works in substantial accordance with the recommendations. Work on plans and specifications were commenced in April, 1922, and contracts for machinery let in July, 1922. To date, practically all work is under contract and construction of the pumping station, pumping equipment, and other portions of the works is well advanced. It is expected that the new works will be completed and in operation early in 1924.

DESCRIPTION OF NEW WATER WORKS

At the Parkway Station the water from the wells enters the equalizing basin which provides for variations between the flow from the wells and the rate of operation of the aerator and iron removal plant. From the equalizing basin the water flows to the secondary pumps in the north end of the pumping station which discharge through a 42-inch cast iron conduit to the aerator. A Venturi meter is provided in this conduit for measuring the flow of water to the aerator.

After passing through the aerator the water goes through the filters of the iron removal plant and then back to the pumping station through another 42-inch cast iron conduit. The purified water will then pass either directly to the high lift pumps for de-

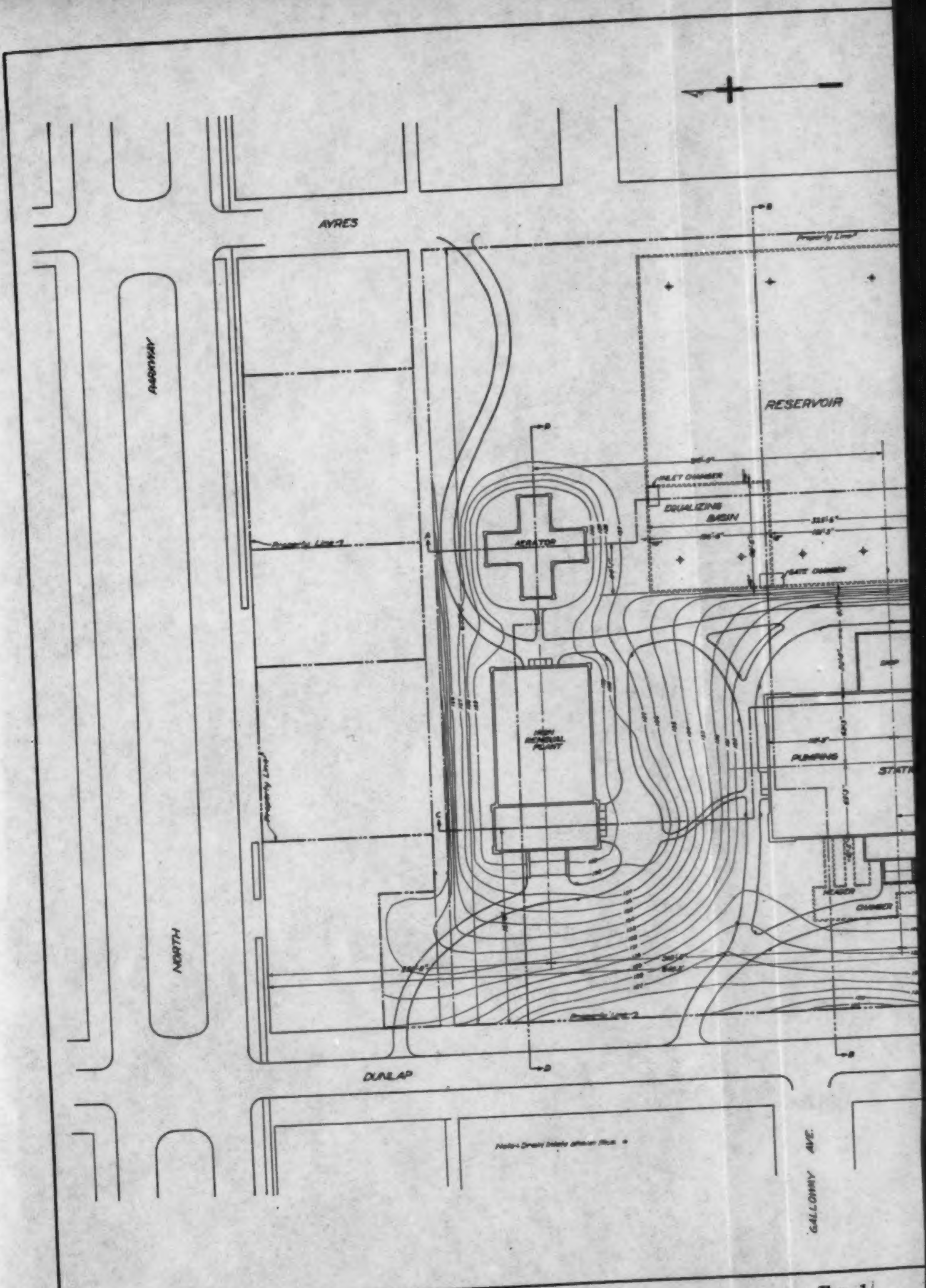

AYRES
PARKWAY
NORTH
RESERVOIR
INLET CHAMBER
EQUALIZING BASIN
GATE CHAMBER
AERATOR
HIGH REMOVAL PLANT
PUMPING
DUNLAP
GALLOWAY AVE.

FIG. 1

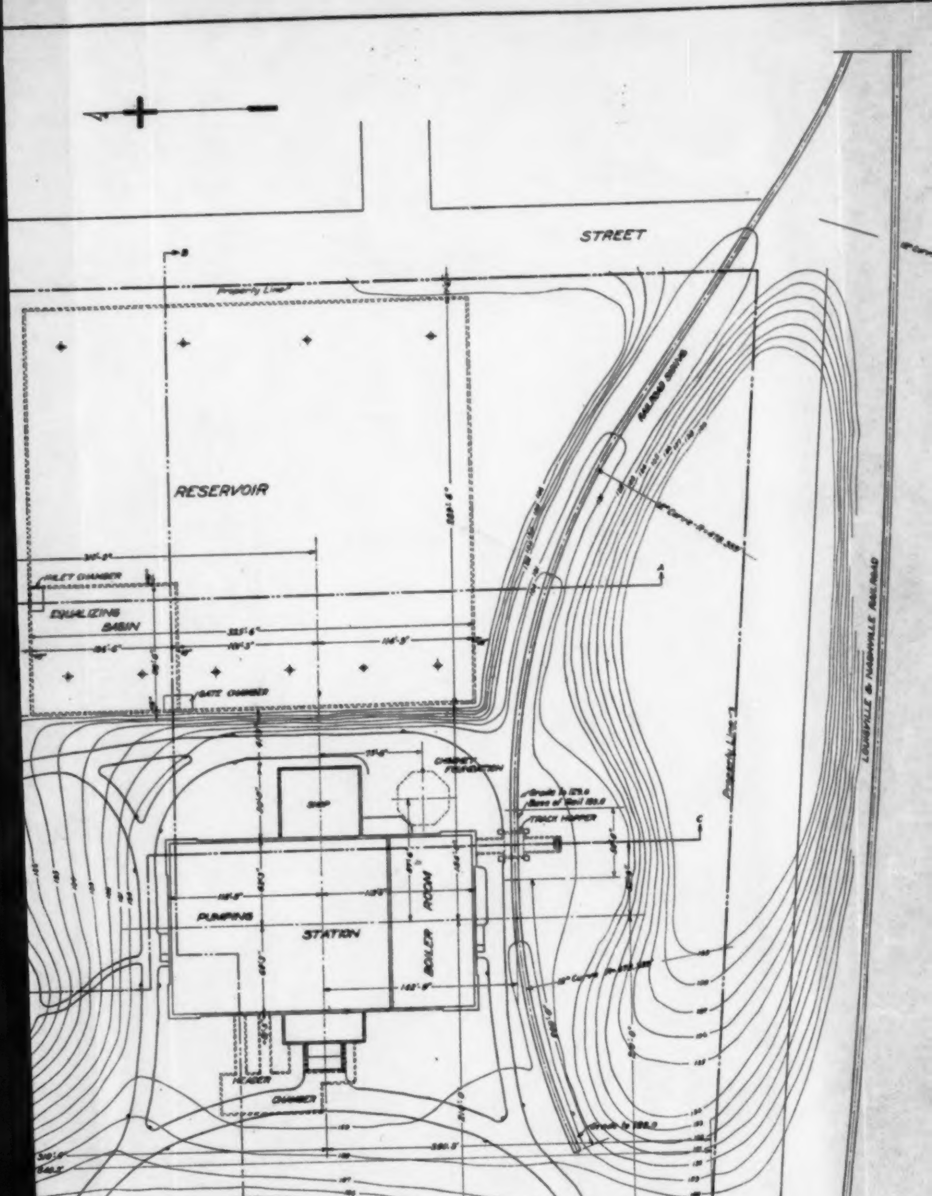

STREET
Property Line
RESERVOIR
INLET CHAMBER
EQUALIZING BASIN
GATE CHAMBER
RAILROAD SIDING
CHIMNEY FOUNDATION
TRACK HOPPER
SHOP
PUMPING STATION
BOILER ROOM
HEADER CHAMBER
LOUISVILLE & NASHVILLE RAILROAD
STREET
GALLOWAY AVE.
Approved Memphis Artesian Water Commission
ARCHITECTS
JONES & FURBRINGER
ENGINEERS
FULLER & McCLINTOCK
170 BROADWAY
NEW YORK

FIG. 1

MEMPHIS TENN.
ARTESIAN WATER DEPARTMENT
PARKWAY STATION
GRADING, RESERVOIR AND SUBSTRUCTURES
CONTRACT 6
FINISHED GRADING PLAN
SEPTEMBER 1922
SCALE 1 INCH = 40 FEET

SHEET 3 OF 20

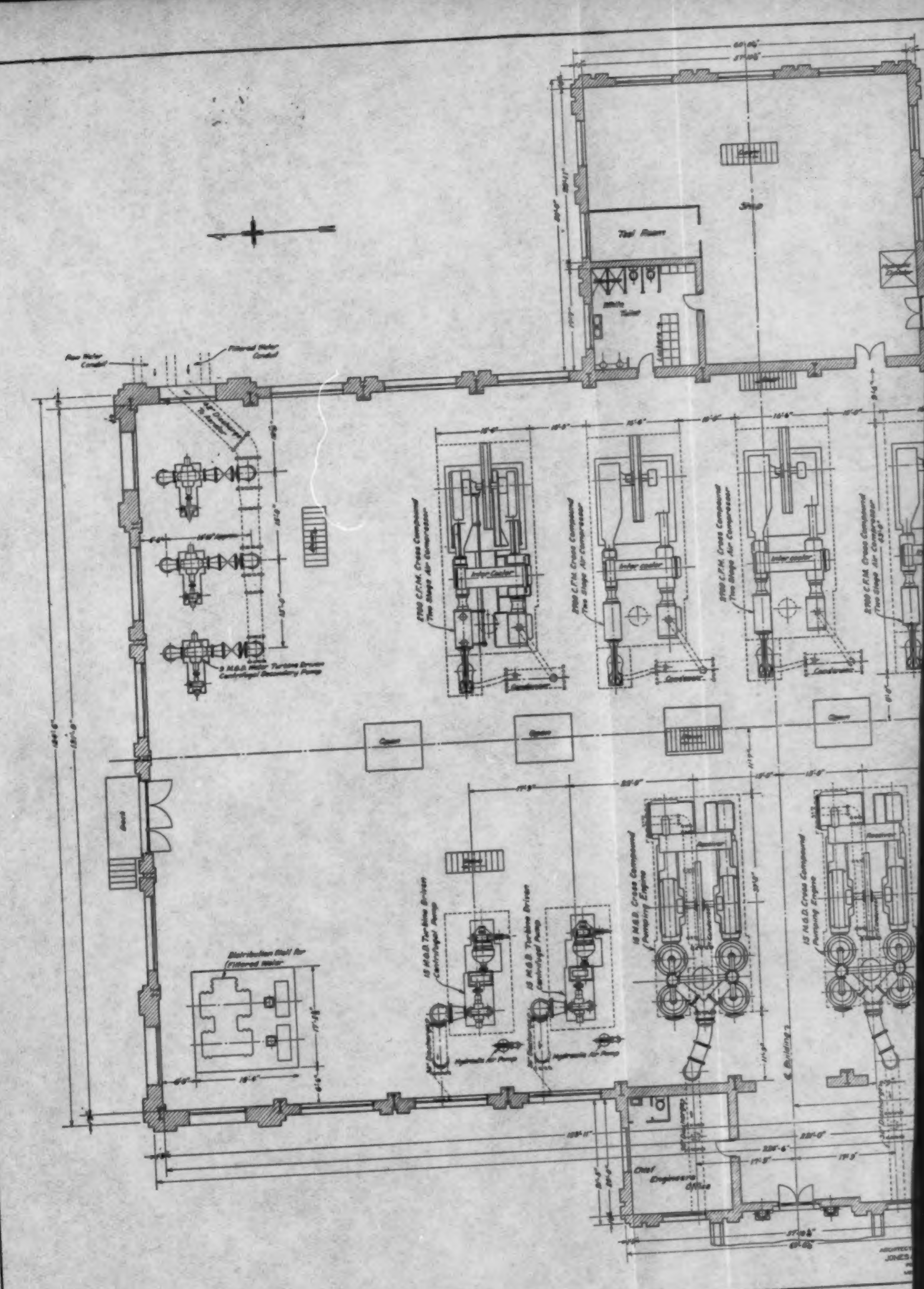
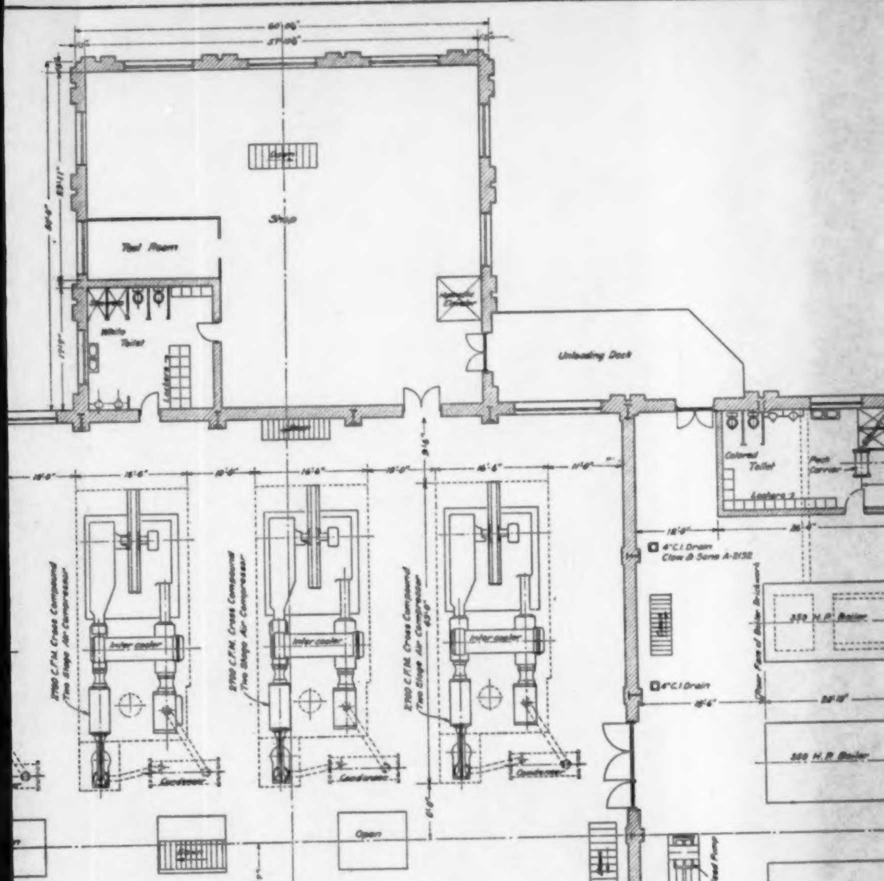
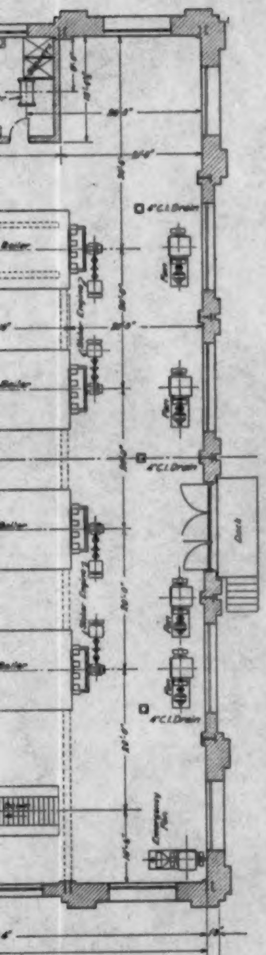


Fig. 2



Tool Room
Shop
White Toilet
Lockers
Unloading Dock
Colored Toilet
Inter cooler
Condenser
Open
Receiver
350 H.P. Boiler
Boiler Feed Pump
Chief Engineers Office
ARCHITECTS
JONES & FURBRINGER
ENGINEERS
FULLER & McCLINTOCK
NEW YORK

Fig. 2



MEMPHIS TENN.
ARTESIAN WATER DEPARTMENT
PARKWAY STATION
SUPERSTRUCTURES, CHIMNEY AND FILTER EQUIPMENT
CONTRACT 7

PUMPING STATION
MACHINERY LAYOUT

OCTOBER 1922
SCALE 1/8 INCH = 1 FOOT

SHEET 4 OF 39

livery to the City, or if there is a surplus, it is discharged through a concrete conduit into the main storage reservoir.

The proposed finished grading plan about the Parkway Station is shown in figure 1. A series of drives have been laid out to give convenient access to all portions of the works and a siding from the L. and N. Railroad is provided for the delivery of coal.

The station is located in a good residential district and it is proposed to make it as attractive as possible by parking the grounds and making the buildings of pleasing architectural appearance.

RESERVOIR AND EQUALIZING BASIN

The reservoir and equalizing basin is a reinforced concrete structure with a total capacity of about 10,000,000 gallons, but one corner is walled off, giving 1,000,000 gallons capacity for equalizing the flow from the wells. The roof is of the flat slab type of construction with panels 18 feet square and is designed for a live load of 100 pounds per square foot in addition to the weight of the earth fill. The reservoir is to be covered with earth and finished as a level terrace on which it is proposed to construct six tennis courts.

PUMPING STATION

In the northwest corner of the sub-structure of the pumping station is located a distribution well to which are connected the duplicate suction conduits, each serving two high lift pumping units, as well as the connecting conduits to the reservoir and iron removal plant. A by-pass connection is also provided from the raw water suction conduit, so that in case of emergency water can be delivered directly from the equalizing basin to the high lift pumps.

In figure 2 is shown the general layout of machinery on the main floor of the station. The four air compressors have been placed in one row and the two crank and fly wheel pumping engines and the two turbine driven centrifugal pumps in a second row, with space allowed for an additional air compressor and an additional turbo-centrifugal pumping unit. This arrangement brings the steam ends of the various units conveniently together for the operating men.

The boiler room occupies the southerly end of the main building and contains the four boilers which are being installed at present, together with space for an additional boiler. The boilers have

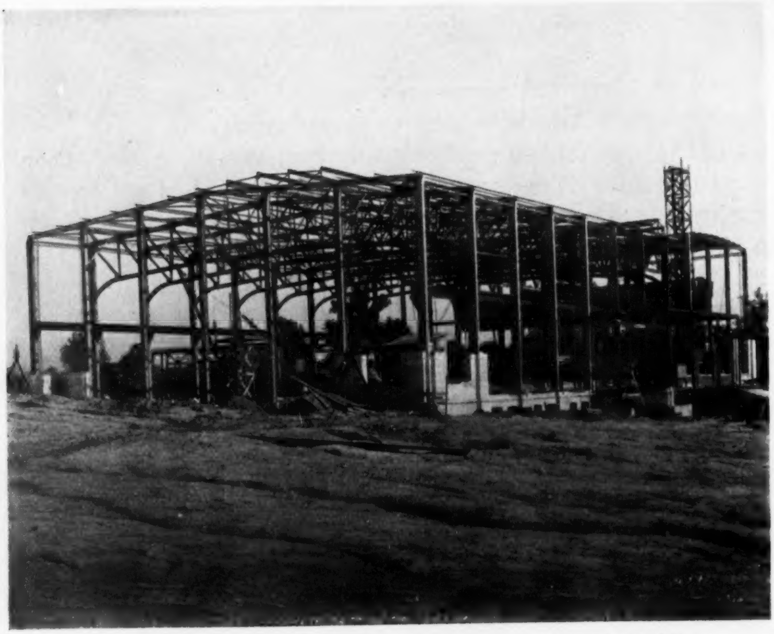


FIG. 3. FRAMEWORK OF PUMPING STATION (MAY 10, 1923)

FIG. 4. INTERIOR OF PUMP ROOM (JULY 25, 1923)

been set in a single row, with ample room at both front and rear, and liberal spaces between boilers. The feed pumps are placed in a row at the rear of the boilers and the motor driven fans located in another row at the front of the boilers.

The three secondary pumping units for delivering water to the aerator are arranged in the northeast corner of the building and space is allowed for an additional unit.

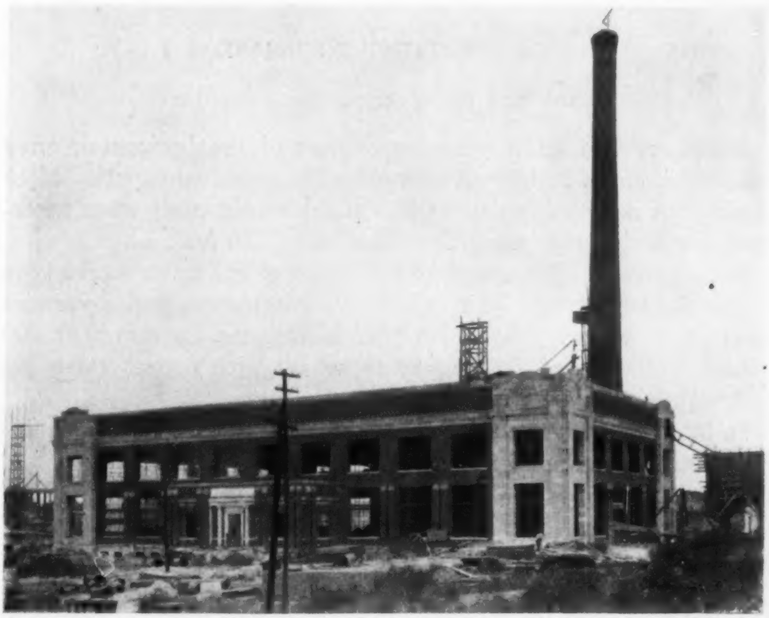


FIG. 5. FRONT VIEW OF PUMPING STATION (SEPTEMBER 15, 1923)

Separate locker and toilet rooms are provided for the white and colored employees as well as an office and toilet room for the chief engineer. At the rear is a shop of liberal size for carrying on necessary small repairs at the station.

The exterior of the pumping station superstructure is being built of mat-face texture brick with a range of shades from gun-metal to light red laid in Flemish Bond. The corner pylons, base course, cornice and other exterior trim are of buff Bedford limestone. The interior of the pump room will be faced with light buff, Kittanning brick. Steel sash will be used throughout and as far as practicable windows have been provided to light the basement.

The placing of the machinery in a double row has necessitated a clear span of about 120 feet for the pump room. The coal bunker is suspended from the boiler room roof trusses which avoids the obstruction of additional supporting columns.

A 15-ton electric travelling crane of 117-foot clear span will serve the pump room.

There is a 12-foot basement under the pump and boiler rooms to accomodate condensers, steam piping and other auxiliaries.

PUMPING STATION EQUIPMENT

Crank and fly wheel pumping engines

There are two Snow pumping engines of the horizontal, cross compound, crank and fly wheel type with a nominal capacity of 15 m.g.d., but designed to deliver 16.5 m.g.d. continuously when necessary, the total head pumped against being 200 feet.

Each unit will have a surface condenser of the water works type in the suction, attached air and condensate pumps, and a vacuum condensate heater. The valve gear is designed for steam at 200 pounds pressure and 200 degrees superheat with poppet valves on the high pressure cylinders.

In table 3 are given the guaranteed duties for the pumping equipment and air compressors. The resultant duty guaranteed for the pumping engines is 143,100,000 foot pounds per 1 million B.T.U. including auxiliaries, this resultant duty being a combination of the duties guaranteed at several capacities as shown.

In view of the direct pumpage into the mains it is expected to use the crank and fly wheel units for most of the work as they will maintain good economy over wide ranges in capacity.

Turbo-centrifugal pumping units

There will be two turbo-centrifugal pumping units, each consisting of a 16-inch single stage Worthington pump, gear driven by a General Electric steam turbine. The capacity of each unit is 16.5 m.g.d. against a total head of 200 feet and the turbines are designed for the same steam conditions as the crank and fly wheel pumping engines.

Each unit will have a surface condenser of the water works type in the suction with a condensate heater. The air pumps will be of the Worthington water jet type and the condensate from each unit

TABLE 3

Guaranteed duties of pumping equipment and air compressors

RATE OF DELIVERY M.G.D.		DUTY IN MILLIONS OF FOOT POUNDS PER ONE MILLION B.T.U. 75° superheat	DUTY IN MILLIONS OF FOOT POUNDS PER ONE MILLION B.T.U. 200° superheat
Snow cross compound pumping engines, 28 inches vacuum, 200 pounds steam			
6.0	w	129	132
10.5	x	141	144
15.0	y	144	147
16.5	z	142.5	145.5
Resultant duty $= \frac{w + x + 2y + z}{5}$		140	143.1
Worthington general electric turbo-centrifugal pumping units 28.5 inches vacuum, 200 pounds steam			
10.0	x	136	139
15.0	y	143	146
16.5	z	142	145
Resultant duty $= \frac{x + 2y + z}{4}$		141	144

Nordberg air compressors, 27.5 inches vacuum, 200 pounds steam

RATE OF DELIVERY CU. FT. PER MINUTE		DUTY IN THOUSANDS OF B.T.U. PER HOUR 75° superheat	DUTY IN THOUSANDS OF B.T.U. PER HOUR 200° superheat
85 lbs. gage air pressure			
1000	x	2200	2040
1800	y	3700	3400
2700	z	5550	5100
Resultant duty $= \frac{x + y + 2z}{4}$	u	4250	3910
100 pounds gage air pressure			
1000	x	2430	2260
1800	y	4060	3180
2700	z	6100	5670
Resultant duty $= \frac{x + y + 2z}{4}$	v	4672	4195
Final resultant duty $= \frac{2u + v}{3}$		4391	4005

will be handled by a centrifugal pump direct connected to a small water turbine. Pressure water from the main discharge line will drive the condensate pump turbine and then pass through the water jet air pump and be returned to the suction conduit. The resultant duty guaranteed was 144,000,000 foot pounds as shown on table 3.

Air Compressors

The four air compressors, which are of the horizontal, cross compound, crank and fly wheel, two stage type are being built by the Nordberg Manufacturing Co. Each unit will have a capacity of 2700 cubic feet net, of air per minute, against a gage pressure of 100 pounds, but will be designed to operate with maximum economy at 85 pounds pressure. The valve gear is designed for the same steam conditions as the pumping units with poppet valves on the high pressure cylinder.

Each unit will have a surface condenser with condensate heater and attached air and condensate pumps. The circulating water for the condensers will be taken from the discharge of the water turbines operating the secondary pumps. The guaranteed heat consumption for the compressors at different capacities is shown on table 3. Two of the compressors will be sufficient for the maximum station load and the two other units are for reserve.

Secondary pumping units

The secondary pumping units, for delivering water to the aerator, are three in number, and each will consist of a horizontal, centrifugal pump direct-connected to a water turbine, driven by pressure water from the high lift pumps. Both pumps and turbines are being built by the Worthington Pump and Machinery Corporation and each unit will have a nominal capacity of 9 m.g.d. against a total head of 26 feet. The overall efficiency of the pumps and turbines will be about 65 per cent which is equivalent, in combination with the high lift pumping engines, to a duty of 93,000,000 foot pounds per 1,000,000 B.T.U. This method of pumping is therefore much more economical than the use of small steam turbine or engine driven units.

In event of a very severe conflagration it is possible to by-pass the aerator and iron removal plant and shut down these units so that the entire capacity of the high lift pumps would be available.

Boiler plant

The boiler plant will comprise four 350 horse power, Casey-Hedges boilers of the horizontally inclined, water tube type with longitudinal drums built for an operating steam pressure of 225 pounds. Each boiler is to be equipped with a Foster superheater and in order to try out the practical advantage of different degrees of superheat, two units have been designed for 75 degrees superheat and the other two for 200 degrees superheat.

Each boiler will have a Sanford Riley, four retort, underfeed stoker with its own driving engine. Forced draft for each stoker is to be furnished by an electric motor driven fan and there will be a reserve fan, steam turbine driven, with air ducts so arranged that it may serve any boiler. The boilers have steel plate casings to reduce air leakage through the setting. To provide liberal combustion space the boilers have been set 12 feet above the floor.

A radial brick stack 225 feet high with an inside top diameter of 9 feet will provide draft for the boiler plant.

An elaborate header system for controlling the discharge from the high lift pumps is provided. There are eighteen 24-inch hydraulically operated gate valves so arranged that no single failure of either a valve or section of piping will put out of service more than one pumping unit or one force main. The hydraulic valves are all controlled from an operating table in the entrance hall of the station. Duplicate sources of pressure water are to be provided to insure operation of the valves at all times. Venturi meters are provided on each pump discharge.

All steam and feed water piping and other important lines have in general been laid out in loops and careful study given to the location of valves and connections so as to secure the greatest reliability of service.

Duplicate 100-k.w. A.C. generators are to be installed, each driven by a Chuse Unaflow engine to furnish 3-phase, 60-cycle current at 240 volts for the operation of the stoker fans, coal handling equipment, crane and shop tools as well as for lighting the station.

A complete central oiling system will be installed with the necessary storage tanks, filters and other appurtenances to supply the different grades of oil required to all main units of the station equipment.

An interesting feature of the station equipment are the four Thomas thermo-electric meters which will be installed, one on each

main air line. These meters will measure accurately the quantity of air delivered under varying conditions of pressure and temperature and will be used to check the total air going to each group of wells as well as to determine the true delivery of the compressors during duty trials.

In order to reduce the lift from the artesian water level to the station and secure a suitable hydraulic gradient for the wells and collecting conduit it was necessary to place the pumping station at a relatively low elevation and construct the reservoir almost wholly in cut. This resulted in a surplus of over 50,000 cubic yards of material which had to be removed from the site.

Iron removal plant

The iron removal plant is essentially a rapid sand filter plant with a nominal capacity of 18 m.g.d. The eight 2.25 m.g.d. filter units are arranged on two sides of a central operating gallery. In the north wing of the head-house are provided an office, toilet and locker rooms and liberal laboratory space. The south end of the head-house is occupied by a chemical room which contains duplicate dry feed lime machines and space for the storage of lime.

A reinforced concrete wash water tank, 35 feet in diameter by 10 feet in depth, with a capacity of 70,000 gallons, occupies the upper part of the head-house.

The superstructure of the iron removal plant will be constructed to correspond with the pumping station. The entrance lobby, laboratory rooms, toilets, and office will have walls of impervious grey brick like the pump room and the filter and chemical rooms will be faced with buff Kittanning brick like the boiler room. The entrance lobby and operating gallery will have red quarry tile floors and the laboratories will have floors of rubber tile.

Reinforced concrete flumes are to be used for the main influent and effluent conduits and drains. The collecting conduits beneath each filter unit are also of reinforced concrete and of relatively large size to reduce friction losses and give uniform distribution of wash water. Each filter unit is to have a central wash trough with twelve lateral gutters, all of reinforced concrete.

The net filtering area of each filter is 825 square feet which is equivalent to practically 360 square feet per m.g.d. of rated capacity. Small cast iron sleeves are to be set in the top of the main under drains, to receive the tees of the perforated lateral pipes.

The plant will have hydraulic valves throughout, controlled from tables on the filter operating floor and each filter unit will discharge through a Simplex rate controller.

The filter strainer system will consist of $2\frac{1}{2}$-inch galvanized wrought iron pipes, spaced 9 inches on centers, with special cast iron tees at the center with long spigots which will be leaded into the floor sleeves. The lateral pipes will have two $\frac{1}{4}$-inch holes spaced every 4 inches, the holes being located 30 degrees from the center line of the bottom of the lateral. The outer ends of each lateral will have special screwed caps provided with lugs for supporting the ends of the lateral and these caps will each be tapped with two $\frac{1}{4}$-inch holes to insure satisfactory washing of the outside edges of the filters.

Aerator

The Aerator substructure is designed in the form of a cross to give large wall area for ventilation. The well water enters through a conduit to a central riser chamber from which it is distributed through four conduits, one for each arm of the cross. The collecting conduits are arranged to bring the aerated water to a trough at the front of the structure where it can be treated with a small dose of lime to remove any residual free carbonic acid. The substructure forms a basin for the aerated water with a capacity of 240,000 gallons through which the water may circulate after the lime is applied.

The aerator units are forty in number, ten being placed in each wing of the structure. The separate units are 2 feet wide by 7 feet long giving a total area of 560 square feet. Each set of ten is arranged on both sides of a central supply conduit at the top and collecting conduit at the bottom and ample space is allowed around each unit to promote free circulation of air. The aerating units have concrete ends, supporting a distribution trough above and with notched sides to support the concrete side boards forming the aerator trays. The outlet from each unit to the collecting conduit is trapped to prevent reabsorption of carbonic acid. On both sides of each wing are provided vents in the floor leading to the outside air to facilitate the removal of the carbonic acid released from the water.

In place of windows in the aerator, perforated grilles of terra cotta are to be inserted in the side walls to promote ventilation and there is also a ventilating monitor over each wing.

The aerator units are so designed that at the top there is a distributing box with concrete sides connecting with the main supply conduit. The bottom of this box is formed of No. 20 corrugated sheet brass or copper, supported on ledges in the concrete sides and also by pieces of brass pipe. This bottom is perforated with $\frac{1}{8}$-inch holes spaced $\frac{5}{16}$-inch apart in both directions.

The aerating troughs are four in number, spaced 9 inches apart one above the other and each trough is about 10 inches in depth. They are formed of concrete side boards supported on notches in the end pieces and held in place by brass bolts. The bottoms of the troughs are constructed of $\frac{5}{8}$-inch mesh brass wire cloth which rests on three brass pipe supports at intermediate points and at the ends is clamped to small brass angles bolted to the end pieces. All metal work of the aerator will be brass or copper on account of the corrosive action of carbonic acid.

The aerating troughs are to be filled with clean crushed coke which will pass a 2 inch ring and be retained on a 1 inch ring.

Well system

The new well system will comprise 23 wells for the present installation, 4 of which are located on the Parkway Station site and the balance easterly along North Parkway and the L. and N. Railroad for a distance of almost two miles. The western portion of the layout of wells provides in general for spacing of the wells about 500 feet apart to avoid undue interference. The wells have 12-inch casings and 50 feet of 10-inch brass strainer of the Cook type. It is expected to secure a yield of about one million gallons daily per well with a draw-down of 25 feet and the average pumping lift from the wells to the surface is estimated at 75 feet. A larger yield per well may undoubtedly be secured in emergencies, but in general it is planned to operate sufficient wells to obtain an economical draw-down rather than attempt to secure the maximum capacity.

It was originally intended to place the wells on the mall in the center of the Parkway, but owing to opposition from property owners, a number of lots were bought for well locations and at the easterly end a strip of land paralleling the L. and N. Railroad was purchased. The collecting conduit and air lines are designed so that several additional wells may be added at the easterly end of the system if desired in the future.

The collecting conduit will be of Class A, cast iron pipe, 36 inches in size at the easterly end; then 42 inches in size and the last 4000 feet consisting of two 36-inch lines. There are three 10-inch and three 6-inch air lines leading from the pumping station to various groups of wells and the main air lines are cross-connected at a number of points to insure greater reliability. Air lines are to be of standard wrought steel pipe with welded joints, except that Dresser couplings will be placed every 350 feet for expansion joints and all valves and fittings will have flanged joints.

Drains are to be built from each well to discharge dirty water when a well is being cleaned or overhauled.

Every effort will be made to make the well development attractive in view of the high class district in which it is located. The well lots will be neatly graded and planted with shrubs and the well houses designed to harmonize with the surroundings.

Each well-house will be arranged so that a portable derrick may be mounted upon the roof when it may be necessary to work on a well.

The wells will be equipped with all necessary gages, controllers and meters so that the air lifts may be carefully regulated and operated in the most efficient manner.

Considerable study is being given to the development of a tapered copper eduction pipe by means of which it is expected to materially improve the efficiency of pumping.

The entire project which will cost about $2,800,000 is being carried out by the Memphis Artesian Water Commission, Messrs. F. G. Prout, Chairman, Milton J. Anderson, Vice-Chairman, and Thomas F. Stratton, Commissioner. Much credit is due to Mayor J. Rowlett Paine for getting under way this important municipal improvement. Mr. James Sheahan is General Superintendent and Mr. Carl E. Davis, Engineer for the Commission.

The works were designed by Fuller and McClintock, Engineers and are being constructed under their direction with Mr. F. G. Cunningham, Resident Supervising Engineer.

THE WATER WORKS COAL PILE[1]

By Donald H. Maxwell[2]

The recent increased cost of coal and the troubles experienced in getting a sufficient supply and of the right quality have brought the coal pile forcibly to the attention of the water works superintendent.

Although the amount of coal required for water works pumping in the United States seems small by comparison with the estimated total coal consumption for all purposes of about six tons per capita, it is nevertheless a considerable amount, and is estimated at approximately three million tons per year. In future years probably much more than this will be required, for even if greater economy is practiced in the use of coal by water works plants, the savings will be more than offset by the increased demand for water by growing city populations, which may reasonably be expected at least to treble. When that time arrives the coal consumption for public water supply on the present basis will be approximately ten million tons per year.

In the meantime the general expansion of industry increases the market for coal while the supply is understood to be definitely limited and capable of development only at increased cost as the more accessible veins and better grades are worked out.

It is apparent that the problem of coal supply and of economic utilization of coal in the water works plant is not only of momentary interest, but is destined to be of constantly increasing importance.

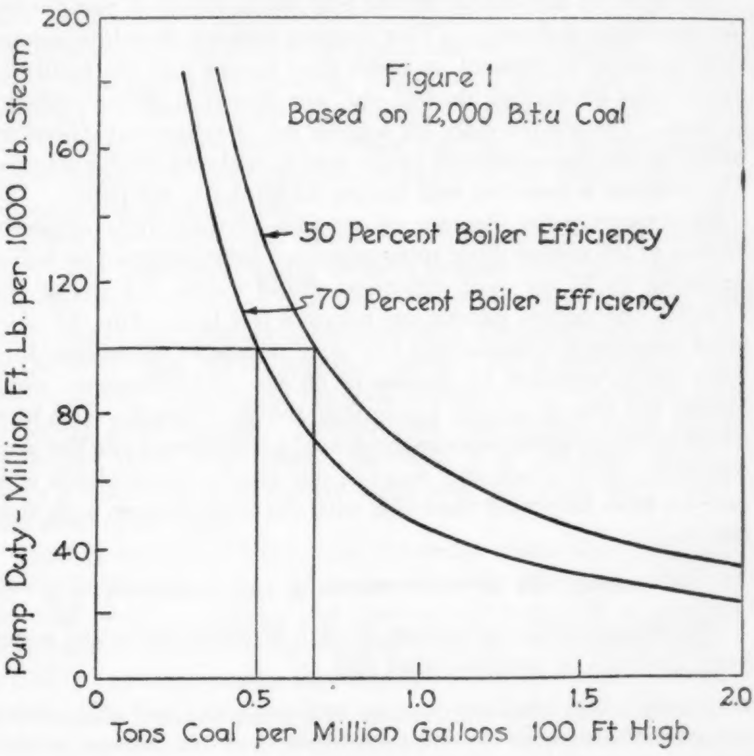
COAL SAVINGS POSSIBLE

There is no doubt but that the water works coal pile, taken as a whole, may be very much reduced. The consulting engineer is in a position to note many instances where pumping plant efficiency might be increased and others where pumpage might be reduced. It is rather striking, for instance, to note that in our second largest city, supplied with water by ten large pumping stations of good efficiency,

[1] Presented before the Detroit Convention, May 25, 1923.

[2] With Alvord, Burdick and Howson, Consulting Engineers, Chicago, Ill.

the waste of water in distribution is so great that the estimated possible saving in coal by metering the services would amount to nearly 100,000 tons a year. This plant is, of course, exceptional, but instances taken at random will be given later on that will be sufficient to indicate that there is, in the aggregate, a considerable waste of coal in water works plants that may be overcome by giving closer attention to boiler room economy, to efficient pumping and to distribution of water without unnecessary waste.



DEVELOPMENTS IN STEAM PLANT ECONOMY

The first requisite to coal economy is efficient equipment. Great strides have been made in the development of pumping plant economy since many of our older water works plants were equipped. In contrast to the hand fired return tubular boiler of small horsepower,

delivering saturated steam at 80 pounds pressure to duplex pumps of very low duty, modern practice calls for stokers, water tube boilers in large units, with superheaters and with good accessory equipment for maintaining high efficiency, and delivering steam at from 200 to 300 pounds pressure and superheated 100 to 200 degrees. The steam is utilized in cross-compound or vertical triple pumps with test duties ranging from 120 to 180 million foot pounds per 1000 pounds steam.

The effect of this change on the coal pile is shown in part (except for superheat) in figure 1. This diagram does not take into account such auxiliary equipment as boiler feed pumps and the incidental uses of coal for station heating, etc., nor does it allow for variation in load. The station duty for a given set of equipment, therefore, would be less than indicated by the coal rates shown on this diagram. The diagram is based on coal having 12,000 b.t.u. per pound.

By inspecting the diagram we see that vertical triple expansion engines of 160 million duty, using saturated steam supplied by boilers operating at 70 per cent efficiency, would require 0.3 ton of coal to pump one million gallons one hundred feet high. On the other hand compound direct-acting low duty pumps of 30 million duty, using steam supplied by boilers of 50 per cent efficiency, would require 2.2 tons of coal to accomplish the same result. One plant would consume seven times as much coal as the other to do the same pumping. It is a fact that many of our smaller steam plants compare no more favorably than this with the more modern high duty station.

ADVANTAGE OF HIGH PRESSURE AND SUPERHEAT

To understand the advantage in high steam pressure and superheat, it should be borne in mind that,

1. Steam engine efficiency increases with steam pressure, amounting in turbo-centrifugal pumps for example to about 1 per cent decrease in steam consumption for each 10 pounds increase in steam pressure.

2. In general, it does not take more coal (to an appreciable extent) to generate steam at relatively high pressure than at low pressure.

3. Engine efficiency increases with superheat, the gain with turbo-centrifugal pumps for example being approximately 1 per cent decrease in steam consumption for each 12° increase in superheat. The great advantage of superheated steam in reciprocating engines is that it does away with cylinder condensation (if superheated enough), so that all of the steam entering the cylinder is available to do useful work throughout the stroke.

4. The additional heat required to superheat steam is much less than the heat saved by the engine, so that there is a saving of coal. Assuming 100° superheat, this fuel saving amounts to about 4 per cent with a turbo-centrifugal unit, 8 per cent with a triple expansion engine and much more with compound and with simple engines.

LIMITATIONS OF WATER WORKS PLANTS

The water works plant is of long life compared with industrial and electric power plants. The opportunities for business expansion, particularly in electric power production, make it good business policy to use only the most modern and efficient equipment. The coal bill in these plants is a relatively large part of the cost of power and accounts for the wholesale discarding of comparatively new equipment and even entire plants to make way for more efficient units of larger capacity in great central stations that will enable the utility to command more business.

The water works plant cannot be rejuvenated in this sweeping way. The business of selling water is in most cities fully developed and may only increase in proportion to the growth of the city. The water works pumping station represents a comparatively small part of the total plant investment and the coal bill is also a small part, comparatively speaking, of the total annual cost of the entire plant, including fixed charges. Furthermore, the requirements for fire protection make it necessary, particularly in the small plant, to carry a relatively large reserve boiler and pump capacity which is idle most of the time.

From these facts it is seen that the water works plant must move slowly in the procession of increased plant efficiency. Only occasionally when an entirely new plant is built to replace an outgrown and obsolete plant does the engineer have the joy of doing what he would like to do in making the plant up-to-date in efficiency of equipment. The usual case involves more or less important additions to existing equipment, the limitations in this old equipment influencing at times very largely the character and efficiency of the new. It is not always financially practicable to change over to 200 pounds boiler pressure and 100 degrees superheat, for instance, in a plant with heavy investment in low pressure pumps and boilers that are still good. The fixed charges on proposed new equipment must always be weighed against the estimated saving in cost of coal, and coal is not high enough yet to warrant the sweeping replacements in the average water works plant that have been good business policy in some electric power plants.

PLANNING FOR THE FUTURE

Even though radical changes in pumping station equipment may not be justified when renewals are necessary, the superintendent has an opportunity at such times, which should not be lost sight of, to map out an improvement program involving the entire plant. It would be most desirable, for instance, in replacing a boiler to make a survey of the plant and its future requirements and, as a result, perhaps find it worth while to install a boiler at comparatively slight increased cost, capable of withstanding a future higher steam pressure and arranged for the installation at a later date of superheaters. When the time then comes to make pump replacements or additions the boilers will not be a handicap. Judicious provision for the future in this way will do much in the course of time to improve the small water works station efficiency without sacrificing useful equipment.

BOILER PLANT OPERATION

Meantime the water works operator must be contented to make the best use of equipment now on hand. Even though the low pressure plant with low duty machinery must continue operating on this basis for some years a great deal may often be accomplished in these plants to reduce coal consumption by close attention to the details of operation that make for efficiency. The watch-word throughout the plant should be: "save the heat units." It might be said that intelligent and conscientious operation of a hand-fired low efficiency boiler installation is even more important for coal economy than in a plant with high efficiency equipment.

Coal saving is not possible without measuring and recording the internal workings of the plant. Between the heat input and measure of work output, there may be a large preventable waste of energy amounting to from 25 to 50 per cent of the coal pile, in a poorly maintained plant. It is not sufficient to know merely the tons of coal purchased and the plunger displacement, and yet, astonishing as it may seem, plants are occasionally encountered in which even this meager information is not obtainable in a satisfactory manner.

The efficient operator must know the pounds of coal burned per hour for a given heat output in steam. He must know whether his customary methods of firing give the best results with the fuel at hand. He must know the effect of his practice in draft regulation, as to whether the boiler is being unnecessarily cooled by too much

excess air or whether unburned gases are being wasted up the stack from insufficient supply of air to the furnace. Among other things he must know the effect of removing soot and boiler scale and how often it pays as a practical proposition to do this.

In a word, the operator should know whether he is wasting coal in the boilers. To find this out he needs the equipment and the interest to make routine boiler tests and periodic flue gas analyses. An intelligent boiler room force and careful training in efficient methods are essential to economical operation. Furthermore, a suitable bonus system based on coal saved would be a valuable stimulus to interest in a coal saving program, if the possible savings seem sufficiently great to warrant it.

TABLE 1

Effect of reducing pump slip on the coal pile

YEAR	PLUNGER DISPLACEMENT	COAL BURNED
	mil. gals.	*tons*
1919	263.1	1124
1920	299.9	1288
1921*	304.8	1264
1922	237.9	770

Coal saved in 1922 = 518 tons = 67 per cent of 1922 coal pile.
* Rebuilt pump back in service in November.

PUMP ROOM OPERATION

Pump room operation has a large influence on the coal pile. The coal robber in this part of the plant is pump slip, though the preventable loss at the steam end may also be considerable.

The output of every pump room should be metered at the station unless there is some other convenient method of checking up on the pump slip, at frequent intervals. The use of venturi meters on discharge lines has become general, but there are still many plants which lack proper equipment of this kind. These plants are as a rule paying heavily for it in the reduced coal pile.

The writer has had occasion to observe some startling results from high pump slip, and there is good reason to believe that this is one of the principal causes of coal waste in many of the stations that lack proper means of measuring the water delivered by the pumps.

Table 1 shows the result in one plant of reducing pump slip. The records of this plant for several years show a continual increase in

the tons of coal burned per million gallons pumped. The coal bill finally became so high that it was decided to have the pumps rebuilt. The effect of improved efficiency of the steam end and of reducing the pump slip is strikingly illustrated by a reduction in the coal consumption amounting to 67 per cent of the coal burned in 1922. Comparison of the 1922 pumpage with that of the two preceding years shows a marked reduction in pumpage as indicated by plunger displacement.

TABLE 2

Effect of higher duty pump on the coal pile

YEAR	PUMPAGE	PER CENT OF TIME NEW PUMP USED	COAL	COAL PER MILLION GALLONS 100 FEET HIGH
	mil. gals.		*tons*	*tons*
1910	1839		4626	1.01
1911*	1919		4873	1.01
1912	2090	60.9	4749	0.965
1913	2241	90.7	4403	0.842
1914	2272	92.6	4562	0.810

Coal saved in 1914 = 1030 tons = 25 per cent of 1914 coal pile.

* Cross-compound pump of 142 million test duty installed.

TABLE 3

Value of testing pump slip as measured by the coal pile

Average daily pumpage	12,000,000 gallons
Slip	3,750,000 gallons
Slip reduced to	700,000 gallons
Total head 153 feet	
Coal per million gallons 100 feet high	0.923 ton
Coal saved per year	1,570 tons

Table 2 shows the effect on the coal pile of introducing a high duty pump to do the work formerly carried on by low duty pumps. In this plant, under the same conditions of operation, the high duty pump accounted for a saving of over 1000 tons per year, amounting to 25 per cent of the 1914 coal pile.

In table 3 is a rather striking illustration of the large coal saving sometimes possible in a comparatively small plant by eliminating excessive slip in a high test duty cross-compound pump. The saving in this case was at the rate of approximately 1600 tons per year, although inspection of the records tended to show that the excessive slip found on test had lasted only about four months. The record

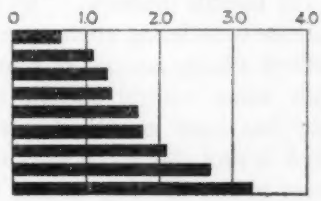
of plunger displacement indicated, however, that, up to within one week of the test, the slip had been materially higher than indicated by the test, and had been partly corrected by replacing pump valves.

Figure 2 illustrates the great difference in coal consumption between stations of the same general type. These are all double pumping stations in small or moderate sized cities operating for the most part under direct pressure. Plant "A" is an eastern plant

Figure 2

COMPARISON OF COAL CONSUMPTION OF STATIONS DOING DOUBLE PUMPING

Plant	Aver Daily Pumpage Mil. Gal.	Total Head Ft	Coal Tons	Coal per Mil Gal 100 Ft High Tons
A	8.83	256	5,317	0.61
B	4.98	240	2,672 *	1.05
C	2.3	280	2,905	1.23
D	0.78	263	648	1 30
E	1.34	221	1,768	1.63
F	2.81	140	2,500	1.74
G	8.98	180	11,940	2.02
H	3.5	190	6,400	2.65
I	2.39	253	7,060	3.2

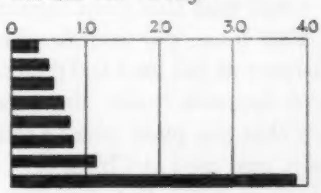


* Seven months period

Figure 3

COMPARISON OF COAL CONSUMPTION OF STATIONS DOING SINGLE PUMPING

Plant	Aver. Daily Pumpage Mil. Gal.	Total Head Ft.	Coal Tons	Coal per Mil. Gal. 100 Ft High Tons
A	62.6	211.5	18,954	0.399
B	3.86	240.	1,800	0.53
C	76.5	115.3	18,452	0.572
D	10.9	283.5	3,237*	0.684
E	603.	109.2	184,368	0.768
F	6.15	251.	4,562	0.810
G	0.65	294.	770	1.10
H	0.5	217.	1,500	3.79



* Five months period

burning Pennsylvania coal. The others are western plants burning Indiana or Illinois coal. The high coal consumption of plant "G" may be partly attributed to wide range in low lift pump head. In Plant "H" it is due partly to poor plant design. In Station "I," the poor showing is due in part to inefficient low lift pumping from the use of over-sized electric centrifugals, the low lift pumping being accomplished at an overall efficiency of 15 per cent for pumps and motors.

Figure 3 shows the typical low coal rate that is expected of well designed and operated modern stations doing single pumping, and contrasts with them the old fashioned stations with low pressure boilers and low duty pumps. Plant "A" is the North Point station at Milwaukee equipped with vertical triple expansion engines of high test duty of about 180 million foot pounds. Plant "B" is an efficiently operated small station burning Pennsylvania coal in hand-fired boilers and pumping with cross-compound engines against constant head. "C" represents the newest and most efficient of the Chicago pumping stations, pumping direct pressure with vertical triple and turbo-centrifugal pumps against a total lift of about 115 feet. Steam is generated by water tube boilers operating at 175 pounds pressure. "E" represents the average of all Chicago stations considering steam pumping only. At three of the Chicago stations a large amount of pumping is done by motor driven centrifugals using central station current. At these stations the coal duty has been greatly decreased from their former performance, which is probably to be accounted for by the unfavorable load on the steam plant. Twenty-second Street now shows a coal rate of 1.41 tons per million gallons, 100 feet high, compared with 0.83 in 1910 and 68th Street shows a coal rate of 1.3 tons compared with 0.85 in 1910.

Plant "D" is the new Des Moines station with stoker-fired boilers, 200 pounds steam pressure and 100 degrees superheat, pumping with turbo-centrifugals of 143 million foot pounds test duty. It should be noted that this plant operates on Iowa coal containing from 8300 to 8800 b.t.u. per pound. The boilers on test showed 72 per cent efficiency at full load and 66.5 per cent at 168 per cent overload. The plant operates under direct pressure. It should be noted particularly that this plant burns a much lower grade of coal than the Illinois steam coal used at Chicago.

Station "F," the old Des Moines pumping station should be compared with Station "D." This station, with hand-fired return tubular boilers and a cross-compound pump of 140 million test duty operating on 125 pounds steam pressure, required 20 per cent more fuel than the new station to accomplish an equivalent amount of pumping.

Station "G" indicates good performance in a fairly well maintained plant operating under 90 pounds steam pressure and duplex compound pumps in good condition, operating direct-pressure under

a high head. Station "H," in contrast to "G," represents poor performance in a plant having equipment of the same general character and burning just as good coal. This latter plant showed 50 per cent boiler efficiency on test and 25 per cent pump slip.

These few illustrations show that, although some pumping plants are operating on a highly efficient basis, others are wasting large quantities of coal. In some of these instances the fault lies in the plant installation and may only be overcome by putting in better equipment. In others, a great deal may be accomplished to improve plant efficiency by systematically checking up on pump slip, boiler firing methods, draft regulation and all other details of operating that affect the size of the annual coal pile.

PNEUMATIC PUMPING UP TO DATE[1]

By John Oliphant[2]

This paper will be in the nature of the experience of a number of years' work in pumping liquids with compressed air, rather than treating the subject in a technical manner. If these experiences should be of benefit to some of you, the object of the paper will have been accomplished.

WELLS

Before going into the subject of pumping, I think it would be proper to consider wells in a general way, as it is from this source of water that most pneumatic pumping is done.

It is rare for the pumping engineer to find a complete record or log of a well; while perhaps the wells are the most important feature about a municipal or industrial plant, the contract for the work seems to be let in a haphazard manner and no record is required from the driller as to what class of material he penetrated—where it was located and its thickness, to say nothing of the kind and size of casing and strainers used. It is no uncommon thing to enter a well that has been represented to be of a certain size to the bottom, and to find that it has been reduced sometimes more than once. This entails considerable loss of time and expense to secure equipment that will go into the hole.

A driller should be required to furnish a complete log and this should be as carefully preserved as the deed to the property.

CONSTRUCTING A WELL IN A SAND OR SAND AND GRAVEL FORMATION

The standard practice of well drillers is to equip gravel and sand wells with a strainer, designed to shut out the sand from the working barrel of a deep well pump. In time, these strainers become clogged with sand and the flow into the well is thus reduced. By a system

[1] Presented before the Philadelphia Convention, May 16, 1922.

[2] Chief Engineer, Pneumatic Pumping Department, Sullivan Machinery Co., Chicago, Ill.

of backblowing, the output from such wells may be permanently increased.

The correct strainer for wells of this class, pumped by the air lift, is a perforated screen with openings of a suitable size to admit the fine material into the well, from which it can be pumped, and to hold back the coarser particles, so as to form a natural gravel filter bed outside of the artificial one.

The force available for getting water into a well is the head due to the difference between the static level in the water stratum outside the well, and the pumping level in the well, minus friction due to the stratum and screen. Therefore, the more this friction can be reduced, the greater will be the flow, providing, of course, that an abundance of water is available.

"*Back-blowing*" may be applied to all wells. The top of the well casing should be sealed. By closing the discharge pipe, while the air lift is in operation, the air will be forced through the foot piece and will drive the water ahead of it through the strainer and float the finer sand. Then, by opening the discharge, the flow will resume its course toward the surface and bring a portion of the floating sand with it. By a repetition of this operation and by increasing the back pressure if necessary, all of the fine sand immediately outside of the strainer will be drawn into the well and discharged at the surface, and the coarser gravel will be collected outside of the screen in such quantities as to shut off the sand and increase the flow into a well, without changing the piping in the well. This process may be repeated at any time, so that the screen and adjacent strata may be kept clear.

When wells are drilled in rock, the action of the drilling tool forces the cuttings back into the crevices in the rock. These may be loosened and pumped out of the well in the same manner.

In the case of wells in fine material and quicksand it is often possible to set a strainer in the sand and drill auxiliary holes alongside the well down to the top of the strainer. Then foreign gravel may be dropped down, which will roll in alongside of the screen and take the place of the sand pumped out, often increasing the yield four-fold, by affording outside of the gravel bed a larger area through which the water may leave the sand.

In the adjoining cuts is shown well construction under three conditions:

1. A well with a properly constructed strainer for air lift work, placed in a mixed layer of sand and gravel.

2. Illustrating the gravel collected around the strainer after the finer sand has been drawn into and pumped out of the well. It will readily be seen that this treatment forms a "gravel" strainer outside of the metal one and greatly increases the inflow area, keeps the

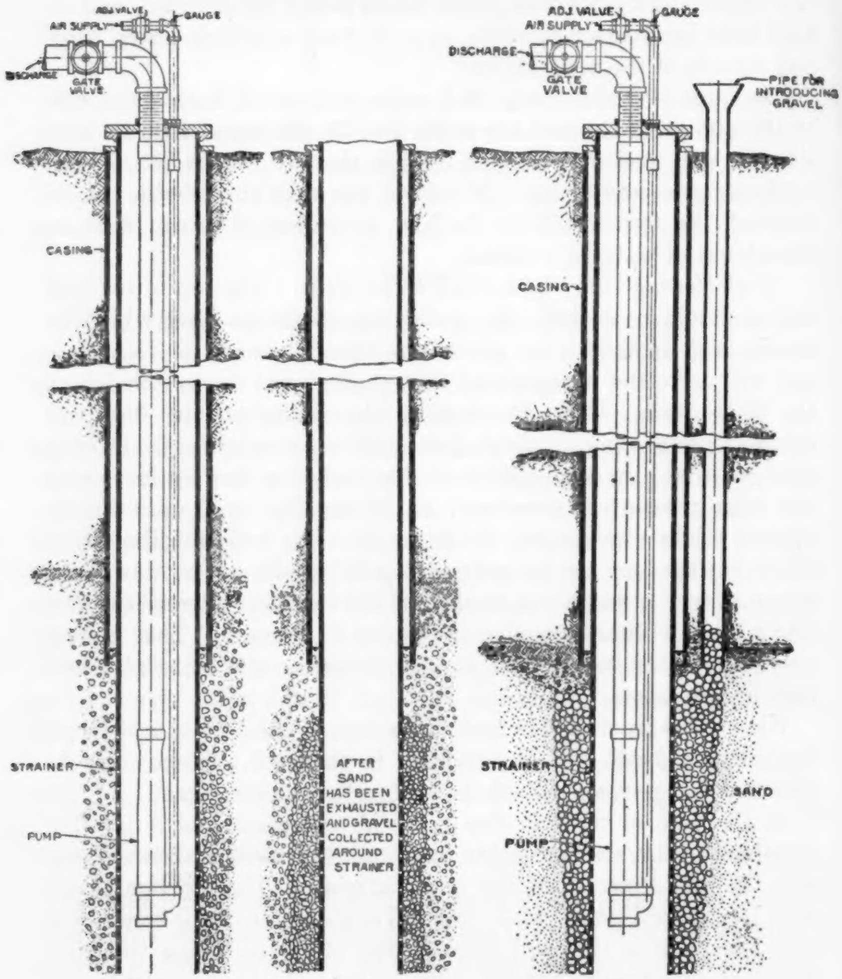


Fig. 1 Fig. 2 Fig. 3

openings of the screen full and open, and greatly increases the capacity of the well.

3. Where the water-bearing layer consists of fine sand, or quicksand, it is sometimes necessary to introduce gravel through one or

more auxiliary holes drilled near the main well and terminating in the top of the sand layer, so that when the sand is removed by "back-blowing," the gravel will roll in around the screen and form a gravel screen outside the metal one as in the first instance. The gravel selected should be clean and practically round; and of size from that of a small walnut up to one which will pass through a two-inch mesh.

PUMPING FROM WELLS WITH COMPRESSED AIR

This method of pumping is becoming more generally used and is deservedly popular for several reasons:

1. More water can be secured from a given well than by any other method, as high as 2200 gallons per minute being secured from a 12-inch well.

2. The character of the water is improved (due to aeration) as to purity and solubility. Recently a very prominent firm of consulting engineers for one of our large cities found that the treatment for the removal of iron was so much less expensive where the water had been lifted with air that they recommended its use, in spite of an apparently higher pumping cost.

3. It is a well known fact that the expanding air absorbs heat from the water and a reduction in temperature is secured. In some ice plants this method is being installed for re-pumping surface water for condensing purposes.

4. As there are no moving parts in the well, no deterioriation is caused by mud, grit, floating sand or long shut downs.

5. As long as the pumping conditions are maintained a sustained efficiency is secured over a long period of time, practically the life of the pipe. If the conditions change and the pumping head drops, a small expense is required to readjust the system to these new conditions.

6. A large system of wells, covering an extensive area, may be operated from a central plant.

The question of submergence is one of the first things to be considered. In actual practice it is found that various submergences may be used for the same lift.

"Submergence" is a term used to express the water head above the point at which the air is admitted to lighten the ascending column and may be in the well or in the strata adjacent to the wells. It is expressed in per cent, 100 per cent being the vertical distance

from the point at which the air enters the water until it leaves it. While there is no definite division line, the following proportions of submergence will be found effective.

	Submergence per cent
Lifts up to 50 feet	70 to 65
Lifts 50 to 100 feet	65 to 55
Lifts 200 to 300 feet	55 to 50
Lifts 300 to 400 feet	43 to 40
Lifts 400 to 500 feet	40 to 35

In proportioning a properly balanced air lift installation there are two principal factors to be considered—slippage and friction. As one is reduced the other is increased and the proper balancing of these two elements of loss makes the most effective installation.

The slippage of a bubble of air through water is in proportion to its size, the larger bubbles slipping faster than the smaller ones. It will readily be seen, therefore, that breaking the air up into small streams and the forming of an emulsion at a point nearest to where the air enters the water is a distinct advantage.

The question of friction is also of paramount importance in determining the areas of the discharge pipe. As there are two elements to be handled, air and water, it is necessary to consider their combined volume. The amount of air depends upon the lift and submergence, therefore the volume handled in the discharge pipe not only changes with the lift, but also changes with the submergence for the same lift. The proper size of piping for handling a certain amount of water under various lifts and submergences is one that should be taken up with a practical engineer having experience along this line of work, as there are so many variants that a cut and dried set of rules is likely to be misleading. Another point in regard to a properly installed air lift that is rarely given the important consideration that it deserves is the smoothness of the discharge piping.

Ordinary commercial piping does not butt joints in the couplings, but leaves a considerable space between the two ends of the pipe, the water and air traveling at a high velocity, especially towards the upper part of the lift, and where the bubbles have expanded to a larger size, strikes the edge of the upper pipe in each coupling, thus causing a swirl and a considerable loss in slippage, amounting at times to 10 per cent. Where a central air line is used the trouble is augmented by the couplings of the air line.

Inserted joint casing or butt joint pipe should be used for the discharge line and also for the air line, where the central system is used.

As the bubbles of air travel with the water to the point of discharge they increase in size, as the head over them is reduced and consequently occupy more space in the ascending column. It is often an advantage to take care of this increased volume with an increased area of discharge pipe. This increase in volume is not uniform but is much more rapid towards the top of the discharge and is frequently the cause of the unequal or plugging discharge which is inefficient and unsatisfactory. The upper part of the column, moving faster, gets away from the bottom and an interval in the discharge of water occurs. A properly expanded pipe will generally correct this, but the expansion should be toward the top of the discharge line.

SUMMARY

I have tried to emphasize the fact that, while the air lift is apparently a simple installation, there are many features about it not generally known and thousands of dollars in coal would be saved annually if careful consideration were given to these facts.

It will certainly pay a municipality or manufacturer having an air lift plant or contemplating the installation of one to have the matter studied by some one who has had practical experience along these lines.

REPORT OF THE FINANCE COMMITTEE FOR THE FISCAL YEAR ENDING MARCH 31, 1923

Your Finance Committee presents the following report on the financial operations of the Association for the fiscal year ending March 31, 1923. The books of the Secretary and the Treasurer have been audited and found correct. All vouchers have been examined and verified. The details of the financial affairs of the Association as set forth in the respective reports of the Secretary and the Treasurer are in accordance with their books.

OPERATING INCOME AND EXPENSE

The Committee has examined and audited the books of the Treasurer and of the Secretary and has found them to be correct, and their cash balances to agree. Since there are certain compensating receipts and expenses, such as reprints of authors' papers, binding cases, etc., representing initial outlays which later are returned, reports of the Secretary and of the Treasurer do not exactly agree, although both are correct. Your Committee has taken the figures as submitted by the Secretary, eliminating compensating expenses and repayments for use in this report.

The 1921–22 Finance Committee, by direction of the Executive Committee, recommended a budget allowance of $20,100.00 for the operating expenses for the fiscal year 1922–23, which was approved by the Philadelphia Convention. This budget was an increase of $4959.66 over the actual disbursements of the fiscal year 1921–22. The actual expenses for the past year, as shown by the Secretary's report, were $19,571.84, while the operating income, as shown by the same report, was $19,451.06, which makes a net profit from operation of $879.22. At the beginning of the last fiscal year on April 1, 1922, the cash balance on hand was $3080.34. At the close of the year it was $3934.40, showing an increase of $854.06. The difference of $25.16 is explainable by the fact that certain expenditures were made as usual by the Secretary's office for binding cases, etc., that are carried on the merchandise account. These items are not charges to the Profit and Loss Account as they represent stock on hand. Your Committee would again recommend

that separate books be kept for these accounts under the head of Property Accounts, and all expenditures and receipts for binding cases, reprints, authors' copies, etc., be kept in this account. In this way a close check could be kept on the miscellaneous receipts and disbursements, and the proper charge for reprints, authors' copies, binding cases, etc., be easily determined. A depreciation charge of $114.49 was used on account of binding cases and old reports, and the net increase in surplus was $764.73. The total surplus on March 31, 1923, was $16,171.91, of which $11,945.00 is invested in bonds and $3934.40 is in cash.

SUMMARIZED STATEMENT OF ACCOUNTS FOR THE FISCAL YEAR ENDING MARCH 31, 1923

Balance on hand in bank April 1, 1922	$3,080.34	
Net income from all sources	19,530.56	
Total income		$22,610.90
Total operating expenses	$18,651.34	
Disbursements for merchandise now on hand	25.16	
Balance on hand in bank April 1, 1923	3,934.40	
		$22,610.90

PERMANENT INVESTMENT FUND

On March 31, 1922, there were in the hands of the Treasurer, by authority granted the Finance Committee by the Executive Committee, certificates constituting the Permanent Investment Fund of the Association, as follows:

	par value
Four (4) $1000 Dom. of Can. 5 per cent Bonds due April, 1931	$4,000.00
Four (4) $500 U. S. 1st Lib. Loan Bonds 3½ per cent	2,000.00
One (1) $1000 U. S. 2d Lib. Loan Bond 4¼ per cent	1,000.00
Two (2) $1000 U. S. 3rd Lib. Loan Bonds 4¼ per cent	2,000.00
Two (2) $1000 U. S. 4th Lib. Loan Bonds 4¼ per cent	2,000.00
One (1) $1000 U. S. Victory Loan Bond 4¾ per cent	1,000.00
	$12,000.00

The Executive Committee, at the Philadelphia Convention in 1922, authorized the Finance Committee, in view of the approaching maturity of some of the bonds, to dispose of such as they saw fit and re-invest the proceeds in high grade bonds of longer term, with the understanding that re-investment of such bonds should be only in bonds which are legal for investments by savings banks in the State of New York. Under this authority, there were disposed of during the past fiscal year, four (4) $500 U. S. 1st Liberty

Loan Bonds 3½ per cent, and one (1) $1000.00 U. S. Victory Loan Bond 4¾ per cent. The proceeds were re-invested in three (3) $1000 U. S. 4¼ per cent bonds maturing October 16, 1952. By this re-investment of funds our income from the permanent investment fund is increased $10.00 per year.

The permanent fund of the Association is at present invested as follows:

	par value
Four (4) $1000 Dom. of Can. 5 per cent Bonds due April, 1931	$4,000.00
One (1) $1000 U. S. 2nd Lib. Bond 4¼ per cent	1,000.00
Two (2) $1000 U. S. 3rd Lib. Bonds 4¼ per cent	2,000.00
Two (2) $1000 U. S. 4th Lib. Bonds 4¼ per cent	2,000.00
Three (3) $1000 U. S. Bonds 4¼ per cent, due October, 1952	3,000.00
	$12,000.00

The Committee believes that the Permanent Investment Funds of the Association should be maintained at all times at a minimum of $12,000.

BUDGET ALLOWANCE AND DISBURSEMENTS

Last year's budget total of $20,100.00 was sufficient to cover all needs and all items came within the amount allowed, with the exception of Convention expenses and Printing of Journal. The actual Convention Expenses were $1104.74, against a budget item of $900.00. This over-draft was paid, by vote of the Executive Committee, by transfer of funds from the Contingencies item. The expense of printing the JOURNAL was $8784.27, against a budget allowance of $8500.00, and the deficiency was covered, by vote of the Executive Committee, by a transfer of funds from Committee Expenses.

The following is a statement of budget allowances and disbursements for the past fiscal year:

Item	*Budget*	*Disbursements*
1. Convention Expenses	$900.00	$1,104.74
2. Office Expenses	1,200.00	1,193.28
3. Committee Expenses	2,250.00	950.24
4. Section Expenses	1,080.00	723.35
5. Insurance	75.00	17.00
6. Secretarial Expense	3,500.00	3,500.00
7. Salary of Editor	1,200.00	1,200.00
8. Printing of JOURNAL	8,500.00	8,784.27
9. Contingencies	315.00	18.96
10. Rent of Office	1,080.00	1,080.00
	$20,100.00	$18,571.84

Items charged against Contingencies were, Exchange of Checks, \$11.76, and Treasurer's Traveling Expense \$7.20, total \$18.96.

The cost of printing JOURNAL, amounting to \$8784.27, against \$7165.40 for the fiscal year 1921–22, shows an increase of \$1618.87. This increase is accounted for largely by the publication of the abstracts of water works literature, which has added materially to the value of our publication.

EXPENSES FOR THE CURRENT FISCAL YEAR

Last year your Committee, by Direction of the Executive Committee, recommended a budget more than \$2000.00 greater than the estimated receipts, with the idea of using our then available cash balance of \$3080.34 to make up any deficiency in revenue. The operating results, as outlined above, show that while our expenses were \$18,571.84 against an estimated revenue of \$18,023.00, that an increase in membership increased our revenue to \$19,451.06, and our cash on hand increased from \$3080.34, to \$3934.40. In view of the above, your Committee, after consultation with the Executive Committee, believes they are justified in recommending the following budget for the year 1923–24, totaling \$23,000.00:

Convention Expenses	\$1,200.00
Office Expenses	1,500.00
Committee Expenses	2,250.00
Section Expenses	1,080.00
Secretarial Expenses	4,000.00
Salary of Editor	1,500.00
Printing of JOURNAL	10,000.00
Rent of Office	1,080.00
Insurance	75.00
Contingencies	315.00

Convention expenses have been increased \$300.00, because the allowance last year was too small.

Office expenses have been increased \$300.00, with the hopes that this increase will allow the Secretary to prosecute a more vigorous campaign for additional members.

Secretarial expenses have been increased \$500.00, so that the Secretary will have sufficient funds to allow him to secure adequate clerical help.

The item for printing the JOURNAL has been increased \$1215.73 over the actual cost for the past year, as it is anticipated that the issue this year will be larger than ever.

AVAILABLE RESOURCES FOR THE FISCAL YEAR 1923–24

On April 1st, 1923, there was a total membership of 1712 divided as follows: Active 1334; Corporate 127; Associate 162; Honorary 3. This is a total increase of 104 for the year, against 68 for the fiscal year 1921–22.

Based on the above, the income would be as follows:

Total from Annual Dues	$13,640.00	
Estimated Initiation Fees	1,400.00	
Estimated Income from Advertisements and subscriptions	3,600.00	
Interest on Investments and Deposits	750.00	
		$19,390.00
Cash on hand April 1, 1923		3,934.40
		$23,324.40

Your Committee believes this a minimum estimate of income.

The Treasurer's report shows a balance of $957.32 in the Electrolysis Investigation Fund. The Treasurer is under bond for $10,000.00, and the Secretary for $2000.00, in accordance with the order of the Executive Committee, and these bonds are in the custody of the Chairman of the Finance Committee.

Your Committee further recommends that the Executive Committee designate those persons whose expenses to the Convention are to be paid by the Association.

Your Committee further recommends that no expenses properly chargeable to any other item of the budget shall be chargeable to the Contingent Fund, and that all items charged against the Contingent Fund for the ensuing year be listed in the next report.

EMIL L. NUEBLING,
J. WALTER ACKERMAN,
GEORGE C. ANDREWS, *Chairman.*

REPORT OF THE JOINT COMMITTEE ON STANDARD SPECIFICATIONS FOR WATER METERS.

To the American and New England
Water Works Associations:

Your Committees on Standard Specifications for Water Meters, acting as a Joint Committee, now submit a final report accompanied by a draft of Standard Specifications for Cold Water Meters of the current, compound and fire-service types. There has not appeared to be any reason for modifying the specifications for meters of the disc type which were adopted by the Associations in 1921.

The specifications for disc meters were printed with the Committee's report which was submitted to the American Water Works Association on June 9, 1921, and to the New England Water Works Association on September 14, 1921, and may be found in the American Association's Journal for that year, page 273, and the New England Association's Journal, page 187. That report was submitted as a final report upon the assumption that a standard specification for disc meters was all that was really needed, since few, if any, meters of other types are bought on the basis of competitive bids. Both Associations, however, indicated their desire that the Committee continue its work and prepare specifications for the other principal types of meters, as well as giving consideration to the experience with the specifications for disc meters with a view to revising them, should any change prove desirable.

The experience of two years with the standard specifications for disc meters has not indicated the desirability of any change.

Your Committee decided to prepare similar specifications for current, compound and fire-service types of cold-water meters. It did not seem necessary or desirable to attempt standard specifications for hot-water meters.

The specifications for disc meters have served as a general basis for those of other types. Through the coöperation of the Standardization Committee of Meter Manufacturers, Mr. R. K.

Blanchard, chairman, a preliminary draft of standard specifications for current and compound meters was prepared. This was circulated to the membership of the Joint Committee and later was discussed in detail at a meeting of the Committee, when certain modifications were decided upon, and it was also agreed to prepare specifications for fire-service meters. The modifications proposed were worked out and incorporated in the draft of specifications on behalf of the Joint Committee by Mr. Edward Nuebling of the Department of Water Supply, New York City, to whom the Committee is greatly indebted for this and for other assistance in its work. The revised draft was further considered by the Committee and by representatives of the meter manufacturers before its adoption in the form now submitted to the Associations.

In connection with the specifications your Committee decided to present certain prefatory notes, including information submitted as addenda to the specifications for disc meters, and other explanatory matter, which it was felt ought to be available in connection with the specifications, although not properly forming a part of them.

It is assumed that after the standard specifications have been adopted by the Associations they will be reprinted, together with the specifications for disc meters, in a single pamphlet for general use.

One point which the Committee does not consider practicable to standardize through the specifications at the present time, but which it is hoped the manufacturers may find it possible to standardize in the not distant future, is the arrangement of dials on meter registers. It is very unfortunate that the sequence of dials should vary with certain makes of meters, but it has not seemed wise to your Committee to attempt to fix a standard in this respect for immediate adoption.

Respectfully submitted,
For the Joint Committee.

CHARLES W. SHERMAN, *Chairman.*

William W. Brush, *Chairman.*
Charles W. Sherman, Henry V. Macksey,
A. W. F. Brown, James A. McMurry,
R. J. Thomas, John H. Walsh,
N. E. W. W. Ass'n Committee.

Caleb M. Saville, *Chairman.*
Dow R. Gwinn,
R. J. Thomas,
Seth M. Van Loan,
Am. W. W. Ass'n Committee.

FEBRUARY 24, 1923.

GENERAL INFORMATION.

(These notes are not a part of the specifications. They are inserted for the purpose of providing proper definitions and general information which is frequently necessary in calling for bids, testing meters, or otherwise passing upon their suitability.)

Types of Meters.

Service meters in use for measuring water delivered to domestic and commercial consumers are divided into four general classes, as follows: displacement, current, compound and fire service.

Displacement Meters. There are a number of different types of displacement meters on the market which are known by the motion of the piston, as, reciprocating, rotary, oscillating and nutating disc meters. These meters are positive in action and displace or carry over a fixed quantity for each stroke or revolution of the piston or disc.

Displacement meters are manufactured in sizes from $\frac{5}{8}$ in. to 6 in. They are suggested for universal use on supply lines to dwellings and for use in other locations where accuracy of measurement is a primary consideration.

Current Meters. There are several different types of current meters on the market which differ from each other mainly in the shape of the water wheel or propeller. These meters are not positive in action, but record the flow by the number of revolutions of their water wheel or propeller, which is set in motion by the force of the flowing water coming in contact with the wheel or propeller blades.

Current meters are manufactured in sizes from $1\frac{1}{2}$ in. to 20 in.* These are cheaper in first cost and maintenance and offer less obstruction to the flow of water through them and therefore give a greater discharge with the same loss of head than displacement meters. They are not sensitive to small flows, and not as accurate and reliable as meters of the displacement class on the larger flows.

Meters of the current type are appropriate where a free discharge and heavy service is demanded, as for example: railroad standpipes, elevators, water carts and water motors.

Compound Meters. Compound meters consist of the combination of a main-line meter of the current or displacement type for measuring large flows and a small by-pass meter of the displacement type for

* Sizes larger than 12 in. are so rare that the Committee has not attempted to give the detailed figures for meters above that size.

measuring small flows, together with an automatic valve mechanism for diverting the small flows through the by-pass meter.

The automatic valve, which is of the differential type, remains closed until the flow is large enough to create a fixed difference in pressure between the inlet and outlet side of the valve. The by-pass meter measures the small flows that otherwise would not be measured or would be measured in part only by the main-line meter. Compound meters are manufactured in sizes from 1½ in. to 12 in. They are suggested for use in cases where flows through the meter cannot be confined to rates within the accuracy limits of a single meter.

Fire-Service Meters. Fire-service meters are compound meters consisting of a main-line meter of the proportional type for measuring large flows and a small by-pass meter of the displacement type for measuring small flows together with an automatic valve mechanism for diverting the small flows through the by-pass meter. The combination is designed to afford a clear passage through the meter when the valve is raised from its seat.

Fire-service meters are manufactured in sizes from 3 in. to 12 in. They are the type required by the Fire Underwriters on sprinkler or fire hydrant connections if minimum fire insurance rates are to be secured. The measurement of flow recorded on the main-line meter is liable to be inaccurate unless careful attention is given to keeping all parts of the meter in good working condition. When the flow through the meter is such as to bring the main-line meter into use, only a relatively small portion of the total flow actually passes through the main-line meter. This increases the liability of serious error in the registration of the water passing through the meter.

Maximum and Minimum Lengths of Meters.

A standard over-all length has been fixed for each size of disc meter. Due to the large variation in the over-all length of each size of current and compound meters that exists among the various makes of meters, it has been found impracticable to fix a standard over-all length for these types. A filler piece can be inserted to increase the length of the shorter meters. Manufacturers are prepared to supply these filler pieces when required.

The following minimum and maximum over-all length, in inches, of the various sizes and types of meters is given to aid those who may desire to provide space for the maximum length of any meter:

Size, Inches.	Disc Standard Length.	Current Minimum Length.	Current Maximum Length.	Compound Minimum Length.	Compound Maximum Length.
$\frac{5}{8}$	$7\frac{1}{2}$	—	—	—	—
$\frac{3}{4}$	9	—	—	—	—
1	$10\frac{3}{4}$	—	—	—	—
$1\frac{1}{2}$	$12\frac{5}{8}$	13	$15\frac{1}{4}$	$18\frac{5}{16}$	$18\frac{5}{16}$
2	$15\frac{1}{4}$	$15\frac{1}{4}$	19	$15\frac{1}{4}$	$28\frac{7}{8}$
3	24	20	24	24	$37\frac{1}{8}$
4	29	22	$29\frac{1}{4}$	29	$39\frac{1}{4}$
6	$36\frac{1}{2}$	24	$36\frac{3}{4}$	36	$50\frac{3}{4}$
8	—	$26\frac{3}{4}$	$48\frac{3}{4}$	42	$61\frac{3}{4}$
10	—	30	60	$63\frac{1}{2}$	$72\frac{3}{4}$
12	—	36	70	$64\frac{1}{2}$	77

Tests of Meters Recommended.

The tests to be made on the meter are divided into two classes:

1. Capacity test.
2. Registration test.

Capacity tests are those which test the design of the meter rather than the workmanship thereof. When a meter of a given make has once been tested for capacity it should not be necessary to again test this type of meter unless a change has been made in its design.

The registration tests should be made on each meter, as the results are affected by workmanship and assembly of individual meters. There is no certainty that, because one meter of a given make comes within certain limits of accuracy, another meter of the same make turned out by the factory on the same day will necessarily give similar results. The register furnished with each meter should be used by both the manufacturer and purchaser in making registration tests.

The registration tests recommended are as follows:

All meters should be tested for accuracy of registration within and as near as practicable to the low and high rates given under "Normal Test Flow Limits." Occasionally additional tests should be made at one or more intermediate points.

A test at the "Minimum Test Flow" should be made on as many as possible and not less than 5 per cent. of the meters. If the results obtained from testing 5 per cent. of the meters show that any meter does not comply with the low-flow requirement, additional

meters should be tested to the extent deemed necessary to make certain that the other meters do comply therewith.

The accuracy of compound and fire-service meters within the "change over" range should be determined by making a sufficient number of tests at different rates of flow between the high and low rates given under "Normal Test Flow Limits" to enable the construction of a representative accuracy curve. The rates of flow at the beginning and end of the "change over" and the maximum error in registration can readily be determined from this curve.

A test for accuracy at the "change over" should not be necessary on all meters since this is a test of design rather than workmanship.

Attempt should not be made to test large-size meters if the higher rates of flow necessary to make a proper test cannot be obtained with the apparatus available.

The pressure test should be made on each size of meter furnished of a particular type. This pressure is to be 150 lb. per sq. in. and the pressure may be furnished through the use if a hand pump or such other method as may be available. Before the meter has been tested by static pressure and also after it has been so tested, it should be tested for accuracy to see whether the meter has been so distorted as to affect registration. It is considered unnecessary to make a pressure test of each size of meter of a given type more than once if satisfactory results are obtained.

If it be possible to give a working-pressure test under 150 lb. per sq. in., then such a test should be applied rather than a static-pressure test.

Where the purchaser does not have the necessary equipment to test the meters, there should be furnished by the manufacturer a certificate that each meter has been tested for accuracy of registration and complies with the standard specifications in this respect, and that the size and type of meter furnished has complied with the capacity requirements. When compound or fire-service meters are purchased, the certificate furnished by the manufacturer should include a statement to the effect that the size and type of meter furnished has complied with the standard specifications in respect to registration of flows within the "change over" from the by-pass meter to the main-line meter.

Equipment Necessary to Test Meters for Compliance with Registration and Capacity Requirements as Set Forth in the Standard Specifications for Water Meters.

The standard specifications require that meters shall accurately record the flow within certain limits and shall pass a given quantity of water with a maximum loss of pressure. Suitable equipment to make accurate tests must be available before the purchaser should make complaint of meters not complying with the specifications.

The minimum test equipment required for registration and capacity is as follows:

1. A quick-acting valve on the supply pipe through the use of which the flow can be started and stopped without appreciable loss of time.

2. A valve on the outlet side of the meter which can be used to establish the rate of flow desired.

3. Pressure gages connected on both the inlet and outlet of the meter to show whether any material change in pressure occurs during the period of test which would affect the rate of flow. The outlet pipe is to have sufficient head on it so that the meter will always have pressure on its outlet end and preferably not less than 5 lb. per sq. in.

4. A measuring device which may be either of the volumetric or weighing type. Whichever is used, the accuracy of determination of the volume or weight of water discharged into the measuring device must be such as to bring the limit of error within one-tenth of 1 per cent. The volume of water passed must be sufficient to cause at least one revolution of the pointer on the initial dial except for test at "minimum test flow" rate. For the latter test, the amount passed shall not be less than one cubic foot.

It is desirable to have available for testing meters a test table and appurtenances which are manufactured by several concerns. Such an outfit would include the equipment enumerated in the preceding four paragraphs.

For the capacity tests, it is necessary to add to the above equipment, two piezometer rings which must be of exactly the same diameter. The piezometer rings must be free from any burrs where the holes are drilled through the wall of the ring and not less than four holes shall be provided, drilled in pairs and on diameters at

right angles to one another. The inlet piezometer ring shall be set close to the meter and shall be at a distance of not less than eight diameters from the nearest upstream stop-cock or fitting in the supply pipe. The outlet piezometer ring shall be placed at a distance of not less than eight nor more than ten diameters from the outlet of the meter. The diameter of the piezometer rings and inlet and outlet pipes shall be the same as the size of the meter to be tested. The piezometer rings are to be connected by either rubber or metal tubing to a mercury U-tube. To this U-tube is to be attached an accurate adjustable scale for measuring the differences between the inlet and outlet pressures. Provision is to be made for the complete removal of air from the tubing connected with the U-tube, and the U-tube and the tubing connected therewith are to be so placed that the air will rise to the outlets. Where relatively high flows are to be recorded, it is necessary to read both sides of the mercury column to compensate, as far as practicable, for irregularities in the diameter of the glass U-tube, and such readings are to be made as nearly simultaneously as possible to avoid errors due to fluctuations.

Information to be Furnished to Meter Manufacturers When Requested to Submit Bids on Meters.

1. Meters shall conform to the Standard Specifications for Cold Water Meters, ... Type, adopted by the American and New England Water Works Associations.

2. The manufacturer shall state in his bid the type of meter he proposes to furnish, as listed in his catalogue. The actual capacity of each size of meter called for is to be given graphically from 0 lb. up to 25 lb. loss of pressure. If this capacity be stated in the manufacturer's catalogue reference may be made thereto.

3. No bid will be considered on meters of a design which has not been listed for at least one year in the catalogue regularly issued by the manufacturer.

4. The method of testing meters shall conform to that recommended by the Committee on Standard Specifications for Water Meters.

5. (*a*)* The meters are to be accepted on a certificate furnished by the manufacturers that the meters have met the requirements of the Standard Specifications for Water Meters, as adopted by the American and New England Water Works Associations.

(*b*)* The meters will be tested by the purchaser to determine whether they do or do not comply with the Standard Specifications for Water Meters adopted by the American and New England Water Works Associations.

6. Registers shall be $\left\{\begin{matrix}\text{round}\\ \text{straight}\end{matrix}\right\}$ reading, and shall record in $\left\{\begin{matrix}\text{cubic feet}\\ \text{gallons}\end{matrix}\right\}$.

Care of Meters.

In all types of displacement and current meters the motions of the piston are transmitted by a system of gearing to the register where the flow is recorded in convenient units of measure, such as cubic feet or gallons. The gearing serves to translate the motions of the piston into the units of measure indicated by the register.

The register is at all times a measure of the number of revolutions of the piston. It records a true measure of flow only when the meter has been properly calibrated by gear adjustment, and, after proper calibration, will continue to register correctly only so long as the piston continues to make the proper number of revolutions for each unit of quantity passed through the meter. If, after calibration, any condition should develop whereby the piston is compelled to make less than the proper number of revolutions per unit of quantity passed through it, the meter will under-register. If the piston is compelled to make more than the proper number of revolutions, the meter will over-register. The proper number of revolutions is the number made at the time the meter is calibrated. The actual number is not important and is ordinarily not determined. There are, under ordinary working conditions, a number of factors that may cause under- or over-registration after comparatively short periods of time. The more important of these factors, which should be guarded against to secure proper registration, are described below:

Excessive Wear. Excessive wear of the moving parts of the meter may be caused by over-speeding, or, in general, by the selection

*Sentence (*a*) is to be used where the purchaser does not have suitable equipment to test the meters. If he has such equipment then sentence (*b*) is to be used.

of meters too small for the work required. The effect of excessive wear of the piston or piston chamber is to cause slippage and under-registration. Excessive wear of the intermediate gear train may cause binding of the gears, breakage of gear teeth or gear slippage. In any case, if the meter is not stopped entirely, under-registration will result. To avoid excessive wear, meters should not be run at destructive speeds.

The rates of flow corresponding to 25-lb. pressure loss, given in the standard specifications for cold-water meters, represent the maximum rates at which water should be passed through meters for short periods of time. They represent peak loads which should come upon meters only at long intervals. These rates would be destructive under continuous service. For continuous 24-hour service meters of the disc or displacement type should not be operated under flows greater than one-fifth the capacity of the meter. Meters of the current type can be operated at higher rates than displacement meters, but for continuous 24-hour service the rate should not exceed one-third the capacity of the meter. If a compound meter is to be used for continuous service at a more or less uniform rate of flow, care should be taken to select a size of meter in which the "change over" point is below the flow which is usually to be measured. Compound meters will not give reliable measurement within the "change over" range; that is to say, within the range covering the change over from by-pass meter to main-line meter.

Temperature. High temperature causes the vulcanized rubber pistons of cold-water meters to expand, tending to create unusual friction or to bind the piston in its chamber. The effect is to cause slippage and under-registration or failure of the meters. Low temperature has no noticeable effect on the working parts of a meter. Freezing will of course stop the meter and possibly damage it.

Cold-water meters are not affected by temperatures up to about 80° Fahrenheit. In warm climates where the temperature of the water is liable to go above 80° Fahrenheit, meters with clearances slightly larger than ordinary should be used. Manufacturers are prepared to furnish such meters upon request.

To avoid troubles due to temperature, meters should be set in locations where they will be protected from heat and frost. In locations where hot water from the heating system may be forced back through the meter or where it may be drawn back when the mains are emptied, a check and relief valve should be installed on the outlet side of the meter.

Corrosion. The metals used in water-meter construction are all affected, more or less, by the corrosive action of the water passed through them. The action is very slow under most potable waters. Its effect is to weaken parts of the meter, particularly the teeth of the intermediate gears. It may also bind meters lying idle for long periods of time. Tuberculation of the outer case in meters of the current type may change the normal direction of flow through the meter and cause over-registration. Vulcanized rubber is but slightly affected by the corrosive action of water, and where the supply is highly corrosive vulcanized rubber intermediate gears are recommended. To avoid possible troubles due to corrosion, particularly when meters are purchased in quantity, the meter manufacturer should be furnished with the chemical and physical analysis of the water supply. Given this information, the manufacturer can use a composition of metal which in his judgment is most suitable for the particular water in question.

Suspended Matter Carried by Water. Foreign matter carried by water in suspension has different effects on different types of meters. In meters of the disc and other displacement types fine particles of suspended matter settling in the meter have a tendency to fill the voids between the piston and piston chamber and cause over-registration. Such over-registration is, however, limited and cannot generally exceed 2 per cent.

In meters of the current type the speed of the piston wheel is proportional to the velocity of flow. Any conditions tending to change the velocity of flow, after the meter has been calibrated, will cause inaccurate registration. Accumulations of deposit always tend to cause over-registration and such over-registration is not limited, as in displacement meters.

All meters, except fire-service meters, are provided with strainers to hold back the larger particles of matter which may be carried in suspension by the water, but the meter strainer will soon become clogged if the water is not kept reasonably free of suspended matter. Sand is especially destructive to all types of meters, and care should be exercised to prevent sand from reaching the supply mains.

The finer particles of suspended matter cannot be prevented from reaching the meter and troubles from this source can be avoided only by cleaning the meter periodically, the interval between cleanings depending upon the quality of the water.

Periodical Tests Necessary to Insure Proper Registration. Water meters, properly selected as to size and type, will give satisfactory service over a long period of years without attention only when operated under ideal conditions. Under ordinary conditions meters must be given a certain amount of care to secure proper registration. In most cases it is impossible to ascertain without actual test whether or not a meter which has been in service is registering within the required degree of accuracy. Consequently, in order to insure reliable meter measurement it is essential that all meters be subjected to periodical tests. The interval between tests and the method of conducting them must be governed largely by local conditions. Under average conditions the following intervals between tests should not be exceeded:

Size of Meter.	Interval Between Test Years.
$\frac{5}{8}$ in., $\frac{3}{4}$ in., and 1 in.	5
$1\frac{1}{2}$ in. and 2 in.	4
3 in.	3
4 in.	2
6 in. and larger	1

Meters of the current and compound type used for measuring unfiltered surface waters should be cleaned about once a year to keep them in good working condition. When filtered or exceptionally clean water is used, the interval between cleanings may be longer.

Best results will be obtained from current meters if they are calibrated in place, since the accuracy of these meters is affected by changes in distribution of velocities through the meter. A meter of this type calibrated in a testing machine under conditions where there is a bend near the inlet side of the meter may register incorrectly from the start, if installed under conditions where there is a straight run of pipe in the inlet side. Any other condition tending to change the distribution of velocities as existent at the time of calibration will have the same effect. If calibrated on premises this source of error will be avoided.

For 3-in. and larger meters the installation of a test tee in the outlet piping makes testing easier and reduces its cost.

STANDARD SPECIFICATIONS FOR COLD WATER METERS.

Adopted by New England Water Works Association, March 13, 1923.
Adopted by American Water Works Association, May 24, 1923.

CURRENT TYPE.

Cases. The outer cases shall be made of bronze composition or of cast iron protected by a non-corrosive treatment. All meters shall have cast on them in raised characters the size and the model, and the direction of the flow through the meter shall be properly indicated. Meters shall be designed for easy removal of all interior parts, without disturbing the connections to the pipe line.

External Bolts. All external bolts shall be made of bronze or of galvanized iron or steel. Nuts shall be designed for easy removal after having been long in service.

Registers. Registers may be either "round" or "straight" reading, indicating in cubic feet or gallons.

All parts of the registers shall be made of non-ferrous material. The maximum indication of the initial dial and the minimum capacity of the register, when indicating cubic feet, shall be as follows:

Size, Inches.	Maximum Indication of Initial Dial. Cubic Feet.	Minimum Capacity of Register. Cubic Feet.
1½	10	10 000 000
2	10	10 000 000
3	10	10 000 000
4	100	10 000 000
6	100	100 000 000
8	1 000	100 000 000
10	1 000	100 000 000
12	1 000	1 000 000 000

All dials, including the initial dial, shall be sub-divided into ten equal parts. All hands or pointers shall taper to a sharp point. They shall be accurately set and securely held in place.

Register Boxes. Register boxes and lids shall be made of bronze composition or same material as the top case, with the name of the manufacturer cast on the lid in raised letters. The serial number of the meter shall be plainly stamped on the lid. If required, the serial number shall also be stamped on the case. The lid shall be recessed and shall lap over the box. The glass shall be inserted from the inside and securely held in place without the use of putty or pins. All register compartments shall be provided with a water-escape hole

$\frac{5}{8}$ in. in diameter, so placed that the change gear or registering mechanism cannot be tampered with.

Connections for 1 1/2 and 2-inch Sizes. Spuds shall be either flanged or tapped, as called for. Flanges may be either of the round or oval type. If of the round type, they shall conform to the American standard of Jan. 1, 1914. If of the oval type, the drilling shall be on the horizontal axis, and in accordance with the American standard bolt circle. If the spuds are to be tapped they shall be tapped for $1\frac{1}{2}$ and 2 in. respectively, with female thread of standard pipe size, and so tapped that Briggs standard pipe thread plug gages may be screwed in by hand up to the notch on the plug.

Couplings shall be made of bronze composition. Nuts shall be tapped 2 and $2\frac{1}{2}$ in. respectively, straight thread, standard pipe size and so tapped that Briggs standard pipe thread plug gages may be backed into the nuts by hand, i. e., the size of the thread in the nut is the maximum size of the Briggs plug, but no larger. Tailpieces shall be threaded $1\frac{1}{2}$ and 2 in. respectively, male thread, standard pipe size, and so threaded that Briggs standard pipe thread ring gages may be screwed on by hand flush with the face of the gage. 2 by $1\frac{1}{2}$-in. and $2\frac{1}{2}$ by 2-in. standard pipe size malleable iron bushings are to be furnished with $1\frac{1}{2}$-in. and 2-in. couplings respectively. Care shall be taken to see that nuts as above described can be screwed on to the bushings by hand and that the face of the bushings will be sufficiently true and square to provide a proper packing surface.

Over-all lengths of tailpieces shall be:

Size.	Length.
$1\frac{1}{2}$ in.	$2\frac{3}{4}$ in.
2 in.	3 in.

Connections for 3, 4, 6, 8, 10 and 12-in. Sizes. Spuds shall be flanged, faced and drilled. If called for, either companion flanges or bell and spigot connections shall be furnished. Companion flanges shall be of cast-iron, faced, drilled and tapped. All flange dimensions, drilling and tapping shall conform to American Standard of Jan. 1, 1914. Bell and spigot connections shall be made of cast iron and shall conform to the cast-iron water pipe specifications, class "B," adopted May 12, 1908, by the American Water Works Association, as far as these specifications will apply thereto. For the 3-in. size the dimensions shall be as follows:

(Letters refer to sketch in Table No. 1 of the A. W. W. A. pipe specifications.)

Actual outside diameter	3.96 in.
Diameter of socket	4.76 in.
Depth of socket	3.50 in.
A	1.25 in.
B	1.30 in.
C	.65 in.

The length of the bell connections from the face of the flanges to the seat of the bell shall be 6 in. for all sizes. The length of the spigot connections from the face of the flange to the end of the spigot shall be 18 in. for all sizes.

Seal Wire Holes. All meters shall have register box screws, inlet and outlet coupling nuts and one or more body bolts drilled for seal wire holes. All seal wire holes shall not be less than $^{3}/_{32}$ in. in diameter.

Measuring Cages. Measuring cages for all meters shall be made of bronze composition and shall be self-contained and easily detached from the main body casing.

Measuring Wheels. The measuring wheel for all meters shall be made of vulcanized rubber. The measuring wheel shall be mounted, or shall rotate, on phosphor-bronze or other suitable metal spindle and shall be supported by jewel, ball, or other suitable bearings. Measuring wheels mounted on spindles shall revolve in hard rubber bushed bearings. The measuring wheel, together with its spindle, shall be as nearly as possible of the same specific gravity as water.

Intermediate Gear Trains. The intermediate gear trains shall be of such construction as to be easily removed and shall be made througnout of non-ferrous material. Gear spindles may run in bearings bushed with hard rubber, provided the bushings are so constructed that they cannot drop out.

Strainers. All meters shall be provided with strainers made of or coated with non-ferrous materials. The strainers shall have an effective straining area at least double that of the inlet and shall be accessible for cleaning.

Registration. The registration on the meter dial shall indicate the quantity recorded to be not less than 97 per cent. nor more than 103 per cent. of the water actually passed through the meter while

it is being tested at rates of flow within the limits specified herein under "normal test flow limits." There shall be not less than 90 per cent. of the actual flow recorded when a test is made at the rate of flow set forth under "minimum test flow."

Size. Inches.	Normal Test Flow Limits. (Gal. per Min.)	Minimum Test Flow. (Gal. per Min.)
1½	12 to 100	5
2	16 to 175	7
3	24 to 400	10
4	40 to 700	15
6	80 to 1 600	30
8	144 to 2 800	50
10	224 to 4 375	75
12	320 to 6 400	100

Capacity. New meters shall show a loss of head not exceeding 25 lb. per sq. in., when the rate of flow is that given in the following table:

Size, Inches.	Gallons per Minute.
1½	100
2	175
3	400
4	700
6	1 600
8	2 800
10	4 375
12	6 400

Pressure Test. Current meters shall be guaranteed to operate under a working pressure of 150 lb. per sq. in. without leakage or damage to any part.

Workmanship and Material. Current meters shall be guaranteed against defects in materials and workmanship for a period of one year from date of shipment. Parts to replace those in which a defect may develop within such period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Rejected Meters. The manufacturer shall at his own expense, replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

Compound Type.

Definition. Compound meters are defined as those meters which consist of the combination of a main-line meter of the current or displacement type for measuring large flows and a small by-pass meter of the displacement type for measuring small flows, together with an automatic-valve mechanism for diverting the small flows through the by-pass meter.

Cases. All outer cases shall be made either of bronze composition or of cast-iron protected by a non-corrosive treatment. All meters shall have cast on them in raised characters the size and the model, and the direction of the flow through the meter shall be properly indicated. Compound meters composed of a combination of independent units in separate housings shall have this information cast on each unit. Meters shall be designed for easy removal of all interior parts without disturbing the connections to the pipe line.

External Bolts. All external bolts shall be made of bronze or of galvanized iron or steel. Nuts shall be designed for easy removal after having been long in service.

Registers. Registers may be either "round" or "straight" reading, indicating in cubic feet or gallons.

All parts of the registers shall be made of non-ferrous material. The maximum indication of the initial dial and the minimum capacity of the register, when indicating cubic feet, shall be as follows:

Size, Inches.	Maximum Indication of Initial Dial. Cubic Feet.	Minimum Capacity of Register. Cubic Feet.
	Main-Line Meters.	
1½	10	10 000 000
2	10	10 000 000
3	10	10 000 000
4	100	10 000 000
6	100	100 000 000
8	1 000	100 000 000
10	1 000	100 000 000
12	1 000	1 000 000 000
	By-Pass Meters.	
⅝	1	100 000
¾	10	1 000 000
1	10	1 000 000
1½	10	1 000 000
2	10	10 000 000
3	10	10 000 000

All dials, including the initial dial, shall be subdivided into ten equal parts. All hands or pointers shall taper to a sharp point. They shall be accurately set and securely held in place.

Register Boxes. Register boxes and lids shall be made of bronze composition or same material as top case, with the name of the manufacturer cast on the lid in raised letters. The same serial number shall be plainly stamped on the lid of both the by-pass and main-line meters. If required, the serial number shall also be stamped on the cases. The lid shall be recessed and shall lap over the box. The glass shall be inserted from the inside and securely held in place without the use of putty or pins. All register compartments shall be provided with a water-escape hole $\frac{1}{8}$ in. in diameter, so placed that the change gear or registering mechanism cannot be tampered with.

Connections for 1 1/2 and 2-in. Sizes. Spuds shall be either flanged or tapped, as called for. Flanges may be either of the round or oval type. If of the round type, they shall conform to the American standard of Jan. 1, 1914. If of the oval type, the drilling shall be on the horizontal axis, and in accordance with the American standard bolt circle. If the spuds are to be tapped they shall be tapped for $1\frac{1}{2}$ and 2 in. respectively, with female thread of standard pipe size, and so tapped that Briggs standard pipe thread plug gages may be screwed in by hand up to the notch on the plug.

Couplings shall be made of bronze composition. Nuts shall be tapped 2 and $2\frac{1}{2}$ in. respectively, straight thread, standard pipe size and so tapped that Briggs standard pipe thread plug gages may be backed into the nuts by hand, i. e., the size of the thread in the nut is the maximum size of the Briggs plug, but no larger. Tailpieces shall be threaded $1\frac{1}{2}$ and 2 in. respectively, male thread, standard pipe size, and so threaded that Briggs standard pipe thread ring gages may be screwed on by hand flush with the face of the gage. 2 by $1\frac{1}{2}$-in. and $2\frac{1}{2}$ by 2-in. standard pipe size malleable iron bushings are to be furnished with $1\frac{1}{2}$-in. and 2-in. couplings respectively. Care shall be taken to see that nuts as above described can be screwed on to the bushings by hand and that the face of the bushings will be sufficiently true and square to provide a proper packing surface.

Over-all lengths of tailpieces shall be:

Size.	Length.
$1\frac{1}{2}$ in.	$2\frac{3}{4}$ in.
2 in.	3 in.

Connections for 3, 4, 6, 8, 10 and 12-in. Sizes. Spuds shall be flanged, faced and drilled. If called for, either companion flanges or bell and spigot connections shall be furnished. Companion flanges shall be of cast iron, faced, drilled and tapped. All flange dimensions, drilling and tapping shall conform to American standard of Jan. 1, 1914. Bell and spigot connections shall be made of cast iron and shall conform to the cast-iron water pipe specifications, class "B," adopted May 12, 1908, by the American Water Works Association as far as these specifications will apply thereto. For the 3-in. size dimensions shall be as follows:

(Letters refer to sketch in Table No. 1 of the A. W. W. A. pipe specifications.)

Actual outside diameter	3.96 in.
Diameter of socket	4.76 in.
Depth of socket	3.50 in.
A	1.25 in.
B	1.30 in.
C	.65 in.

The length of the bell connections from the face of the flange to the seat of the bell shall be 6 in. for all sizes. The length of the spigot connections from the face of the flange to the end of the spigot shall be 18 in. for all sizes.

Seal Wire Holes. All meters shall have register box screws, and one or more bolts of each cover or cap giving access to the working parts of the meter, drilled for seal wire holes. Meters having the by-pass unit in a separate housing shall have the by-pass coupling or connections drilled for seal wire holes. All seal wire holes shall not be less than $^3/_{32}$ in. in diameter.

Measuring Chambers and Cages. The measuring chambers and cages for all meters shall be made of bronze composition, and shall be self-contained and easily detached from their main body casings.

Measuring Pistons. The measuring pistons or discs of the displacement type meters shall be made of vulcanized rubber and shall be fitted accurately but freely in their chambers. Vulcanized rubber disc pistons shall have a metal reinforcement or a thrust roller.

Measuring Wheels. The measuring wheels of the current type meters shall be made of vulcanized rubber and shall be fitted accurately, but freely, in their chambers. The measuring wheel shall

be mounted or shall rotate on phosphor bronze or other suitable metal spindle, and shall be supported by jewel, ball, or other suitable bearings. Measuring wheels mounted on spindles shall revolve in hard-rubber bushed bearings. The measuring wheel, together with its spindle, shall be as nearly as possible of the same specific gravity as water.

Intermediate Gear Trains. The intermediate gear trains shall be of such construction as to be easily removed and shall be made throughout of non-ferrous material. Gear spindles may run in bearings bushed with hard rubber, provided the bushings are so constructed that they cannot drop out.

Strainers. All meters shall be provided with strainers made of or coated with non-ferrous materials. The strainers shall have an effective straining area at least double that of the inlet and shall be accessible for cleaning.

Controlling Valves. The controlling valve mechanism shall be made of bronze composition with phosphor bronze spindles, or of other suitable non-ferrous material. The valve shall cut off all flow through it when the main-line meter is not in operation and shall not bind or stick in service.

Registration. The registration on the meter dials shall indicate the quantity recorded to be not less than 97 per cent. nor more than 103 per cent. of the water actually passed through the meter while it is being tested at rates of flow within the limits specified under "Normal Test Flow Limits," except in the registration of flows within the "change over" from by-pass meter to main-line meter. The registration at these rates of flow shall not be less than 85 per cent. The difference in the rate of flow at the beginning and at the end of the "change over" shall not exceed the figures given in the following table:

Size, Inches.	Gallons per Minute.
1½	20
2	32
3	63
4	100
6	200
8	320
10	460
12	620

The beginning of the "change over" is when the accuracy of registration falls below 97 per cent. due to the automatic valve mechanism, and the end of the "change over" is when the accuracy of registration again reaches 97 per cent.

There shall not be less than 90 per cent. of the actual flow recorded when a test is made at the rate of flow set forth under "minimum test flow."

Size Main Meter, Inches.	Normal Test Flow Limits. (Gal. per Min.)	Minimum Test Flow. (Gal. per Min.)
1½	2 to 100	½
2	2 to 160	½
3	4 to 315	1
4	6 to 500	1½
6	10 to 1 000	3
8	16 to 1 600	4
10	32 to 2 300	8
12	32 to 3 100	14

Capacity. New meters shall show a loss of head not exceeding 25 lb. per sq. in., when the rate of flow is that given in the following table:

Size, Inches.	Gallons per Minute.
1½	100
2	160
3	315
4	500
6	1 000
8	1 600
10	2 300
12	3 100

Pressure Test. Compound meters shall be guaranteed to operate under a working pressure of 150 lb. per sq. in. without leakage or damage to any part.

Workmanship and Material. Compound meters shall be guaranteed against defects in materials and workmanship for a period of one year from date of shipment. Parts to replace those in which a defect may develop within such period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Rejected Meters. The manufacturer shall at his own expense replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

Fire Service Type.

Definition. Meters for fire service are defined as those meters which consist of the combination of a main-line meter of the proportional type for measuring large flows, and a small by-pass meter of the displacement type for measuring small flows, together with an automatic valve mechanism for diverting the small flows through the by-pass meter; the combination affording a clear passage through the meter when the main-line valve is raised from its seat.

Cases. All outer cases shall be made either of bronze composition or of cast iron protected by a non-corrosive treatment. All meters shall have cast on them in raised characters the size and the model, and the direction of the flow through the meter shall be properly indicated. Meters composed of a combination of independent units in separate housings shall have this information cast on each unit. Meters shall be designed for easy removal of all interior parts without disturbing the connectons to the pipe line.

External Bolts. All external bolts shall be made of bronze, or of galvanized iron or steel. Nuts shall be designed for easy removal after having been long in service.

Registers. Registers may be either " round " or " straight " reading, indicating in cubic feet or gallons.

All parts of the registers shall be made of non-ferrous material. The maximum indication of the initial dial and the minimum capacity of the register, when indicating cubic feet, shall be as follows:

Size, Inches.	Maximum Indication of Initial Dial. Cubic Feet.	Minimum Capacity of Register. Cubic Feet.
	Main-Line Meters.	
3	10	10 000 000
4	100	10 000 000
6	100	100 000 000
8	1 000	100 000 000
10	1 000	100 000 000
12	1 000	1 000 000 000
	By-Pass Meters.	
1½	10	1 000 000
2	10	10 000 000
3	10	10 000 000
4	100	100 000 000
6	100	100 000 000

All dials, including the initial dial, shall be sub-divided into ten equal parts. All hands or pointers shall taper to a sharp point. They shall be accurately set and securely held in place.

Register Boxes. Register boxes and lids shall be made of bronze composition or same material as top case, with the name of the manufacturer cast on the lid in raised letters. The same serial number shall be plainly stamped on the lid of both the by-pass and main-line meters. If required, the serial number shall also be stamped on the cases. The lid shall be recessed and shall lap over the box. The glass shall be inserted from the inside and securely held in place without the use of putty or pins. All register compartments shall be provided with a water-escape hole $\frac{1}{8}$ in. in diameter, so placed that the change gear or registering mechanism cannot be tampered with.

Connections. Spuds shall be flanged, faced and drilled. If called for, either companion flanges or bell and spigot connections shall be furnished. Companion flanges shall be of cast iron, faced, drilled and tapped. All flange dimensions, drilling and tapping shall conform to American Standard of Jan. 1, 1914. Bell and spigot connections shall be made of cast iron and shall conform to the cast-iron water pipe specifications, class "B," adopted May 12, 1908, by the American Water Works Association, as far as these specifications will apply thereto. For the 3-in. size dimensions shall be as follows:

(Letters refer to sketch in Table No. 1 of the A. W. W. A. pipe specifications.)

Actual outside diameter	3.96 in.
Diameter of socket	4.76 in.
Depth of socket	3.50 in.
A	1.25 in.
B	1.30 in.
C	.65 in.

The length of the bell connection from the face of the flange to the seat of the bell shall be 6 in. for all sizes. The length of the spigot connections from the face of the flange to the end of the spigot shall be 18 in. for all sizes.

Seal Wire Holes. All meters shall have register box screws, and one or more bolts of each cover or cap giving access to the working parts of the meter, drilled for seal wire holes. Meters having the by-pass unit in a separate housing shall have the by-pass coupling

or connections drilled for seal wire holes. All seal wire holes shall not be less than $^3/_{32}$ in. in diameter.

Measuring Chambers and Cages. The measuring chambers and cages for all meters shall be made of bronze composition, and shall be self-contained and easily detached from their main body casings.

Measuring Pistons. The measuring pistons or discs of the displacement type meters shall be made of vulcanized rubber and shall be fitted accurately but freely in their chambers. Vulcanized rubber disc pistons shall have a metal reinforcement or a thrust roller.

Measuring Wheels. The measuring wheels of the current type meters shall be made of vulcanized rubber and shall be fitted accurately, but freely, in their chambers. The measuring wheel shall be mounted or shall rotate on phosphor bronze or other suitable metal spindle, and shall be supported by jewel, ball, or other suitable bearings. Measuring wheels mounted on spindles shall revolve in hard-rubber bushed bearings. The measuring wheel, together with its spindle, shall be as nearly as possible of the same specific gravity as water.

Intermediate Gear Trains. The intermediate gear trains shall be of such construction as to be easily removed and shall be made throughout of non-ferrous material. Gear spindles may run in bearings bushed with hard rubber, provided the bushings are so constructed that they cannot drop out.

Main Line Controlling Valves. The controlling valve shall be either of the atmospheric or mechanical type, in which the initial resistance to opening practically disappears after opening. The atmospheric valve shall open under a difference in pressure, between the inlet and outlet sides of the meter, not exceeding 6 per cent. of the available pressure. The mechanical valve shall open under a difference in pressure not exceeding 4 lb. to the sq. in.

The controlling valve mechanism shall be made of bronze composition with phosphor bronze spindles or of other suitable non-ferrous materials. The valve shall cut off all flow through it when the main-line meter is not in operation. It shall effectively prevent backflow and shall not bind or stick in service.

By-Pass Check Valve. All meters shall be provided with check valves on the by-passes. The check valve mechanism shall be made of bronze composition or of other suitable non-ferrous material. They shall effectively prevent backflow and shall not bind or stick in service.

Registration. Registration on the meter dials shall indicate the quantity recorded to be not less than 97 per cent. nor more than 103 per cent. of the water actually passed through the meter while it is being tested at rates of flow within the limits specified under "Normal Test Flow Limits," except in the registration of flows within the "change over" from by-pass meter to the main-line meter. The registration at these rates of flow shall not be less than 85 per cent. The difference in the rate of flow at the beginning and at the end of the "change over" shall not exceed the figures given in the following table:

Sizes, Inches.	Gallons per Minute.
3	63
4	100
6	200
8	320
10	460
12	620

The beginning of the "change over" is when the accuracy of registration falls below 97 per cent., due to the automatic valve mechanism, and the end of the "change over" is when the accuracy of registration again reaches 97 per cent.

There shall be not less than 90 per cent. of the actual flow recorded when a test is made at the rate of flow set forth under "minimum test flow."

Size, Inches.	Normal Test Flow Limits. (Gal. per Min.)	Minimum Test Flow. (Gal. per Min.)
3	8 to 400	2
4	8 to 700	2
6	16 to 1 600	4
8	28 to 2 800	7
10	48 to 4 375	12
12	48 to 6 400	12

Capacity. New meters shall show a loss of head not exceeding 4 lb. per sq. in., when the rate of flow is that given in the following table:

Size, Inches.	Gallons per Minute.
3	400
4	700
6	1 600
8	2 800
10	4 375
12	6 400

Pressure Test. Fire service meters shall be guaranteed to operate under a working pressure of 150 lb. per sq. in. without leakage or damage to any part.

Workmanship and Material. Fire service meters shall be guaranteed against defects in materials and workmanship for a period of one year from date of shipment. Parts to replace those in which a defect may develop within such period shall be supplied without charge, piece for piece, upon the return of such defective parts to the manufacturer thereof or upon proper proof of such defect.

Rejected Meters. The manufacturer shall at his own expense replace or satisfactorily readjust all meters rejected for failure to comply with these specifications.

DISCUSSION

WATER INTAKES AND FISH

When it is known that a journey must end in disaster all reasonable efforts should be made to prevent the traveler from getting a good start. If fear is an important factor that may be righteously employed. If a tendency to turn aside is due to little understood or unrecognized influences that tendency should be encouraged. In fact almost any steps should be taken or any conditions introduced to avoid destructive results when those are known to be otherwise unavoidable.

These commonplace observations occurred to the writer as he read Mr. Metcalf's appeal for assistance in behalf of some of his very numerous clients and of himself.[1]

Did the author fail to realize that the traffic was all in one direction? He must have known in designing or re-designing that no return trips were provided. Death was in the air, and water too, at the distant station. There are few cases where design and construction become so merciless. That feature is emphasized as we think how each victim quickens the current and hastens the moment when innocent comrades must meet a similar fate. Elementary principles have been overlooked. Even in the Black Hole in Calcutta every brave Englishman in dying was comforted by the fact that his death increased the chance his comrades would live.

Many years ago the writer was obliged to think about questions similar to those asked by the author. There were fresh lake waters, depth 20 to 25 feet; distance from shore 1000 to 2000 feet and a community fond of water and fish—taken separately. All this led to a design for intakes that has been sketched and described in engineering journals and elsewhere and may again be referred to, briefly, as a vertical cylinder, closed except for small openings and the area of the intake pipe or elbow that "looks upward" through the lower end. The cylinder of metal $\frac{3}{8}$ inch in thickness, some

[1] Journal, July, 1923, page 595.

8 feet in diameter and 6 feet in height is pierced by fourteen to sixteen thousand $\frac{3}{8}$ inch holes, roughly punched and asphalt painted.

A fish like a Ford moved forward by applied energy, from the rear chiefly, and both will get through many cross currents and over many obstacles, but the fish has a vertebral-column quality sufficiently human (even if the column is horizontal) to check his approach to a dark pocket through a small hole. He may pass near and even feel the draft, unlike anything felt before. He has moved with the current but was never pulled by the nose when no bait tempted him. He turns aside and is able to do so for there is no broad strainer surface to hold him and show his especial weakness. A fish cannot move laterally or sidewise, nor can a Ford or a battleship. The result is that the fatal journey is not begun.

For the actual measure of protection thus extended to small fishes inquiry can be made of Mr. Robert J. Campbell, Superintendent of Water Supply, Menominee, Michigan.

H. F. Dunham.[2]

[2] Civil Engineer, 32 W. 40th Street, New York, N. Y.

SOCIETY AFFAIRS

ILLINOIS SECTION

The fifteenth annual meeting of the Illinois Section was held at the Hotel Orlando, Decatur, Ill., on March 21 and 22, 1923. The attendance was excellent and the program subjects elicited much discussion. The order of activities follows:

Afternoon Session, March 21

Address of Welcome—Hon. C. M. Borchers, Mayor of Decatur.

Report of Secretary—G. C. Habermeyer.

Report of Treasurer—H. E. Keeler.

Water Works Development at Mt. Pulaski—Alex Van Praag, Jr.

Recent Developments in the Field of Stray Current Electrolysis[1]—R. E. Shepard.

The Public Utility Fuel Problem—C. M. Roos.

Round Table Discussion—Water meters, service and maintenance—Led by W. E. Lautz.

Evening Session, March 21

The program was presented at the annual dinner at the Hotel Orlando in the following sequence:

Decatur Water Supply—Wilson M. Bering.

Decatur Sanitary District—F. D. Holbrook.

Decatur Water Supply and Sewerage Improvements—S. A. Greeley.

Morning Session, March 22

Municipal Water Softening in Illinois—A. M. Buswell.

Customer Ownership of Public Utility Securities—F. C. Amsbary.

Inspection and Supervision of Filtration Plants in Ill.—H. F. Ferguson.

Round Table Discussion: Filtration Plant Operation—Led by W. R. Gelston.

[1] Journal, July, 1923, page 603.

Afternoon Session, March 22

Luncheon was served at the plant of the H. Mueller Manufacturing Company. Inspection trips were made to the Decatur dam, the water filtration plant, the sewage treatment plant and the pumping plant of the Staley Manufacturing Company.

NEW YORK SECTION

A meeting was held at Rochester, N. Y., on April 21, 1923, which was attended by 106 members. The meeting was addressed by Alvin H. Dewey, Manager of the Rochester and Ontario Water Company. Considerable enthusiasm meets these informal meetings, which will be continued in the future.

NOTICE

The Waco City Water Board, City Health Department and Baylor University, with the State Health Department and Texas and Southwest Water Works Associations co-operating, will conduct a free short course of practical instruction for water works attendants and filter plant operators at Waco, during the week beginning January 21st, 1924.

You are most cordially invited to participate.
Anyone interested may attend.
No charge for tuition or laboratory fees.
No expense except that actually incurred in making the trip.
Conditional class reservations should be made in advance.

Kindly indicate your intention to attend, or name some other local representative that may be present, to Dr. W. T. Gooch, care of Baylor University, Waco, Texas, or to Mr. V. M. Ehlers, State Sanitary Engineer, Austin.

ABSTRACTS OF WATER WORKS LITERATURE

Frank Hannan

Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

A Departure in Water-Works Intakes. C. M. Daily. Eng. News-Record, 90: 884, 1923. Experience with two tower intakes in Mississippi River at Chain of Rocks led to adoption of shore intake for Missouri River plant. Intake will be protected by suitable dike work. Little trouble is anticipated from sand or flowing ice.—*Frank Bachmann.*

Aeration of Water Immediately after Alum Dose Saves Soda. Malcolm Pirnie. Eng. News-Record, 90: 883–4, 1923. Experiments on the Dan River water at Danville, Va., using alum and soda as coagulants, showed that by aerating water immediately after addition of chemicals, excellent floc formed with less chemical than without aeration. Aeration liberates CO_2, thus lowering acidity with more favorable conditions for floc formation.—*Frank Bachmann.* (*Courtesy chem. Abst.*)

Lubrication Saves $2500 Replacement of Water-Main Valve. W. W. Brush. Eng. News-Record, 90: 883, 1923. A 48-inch valve in New York City took several men to operate it twice daily by hand. By installing oil cup to lubricate the thrust bearing, excessive friction was eliminated.—*Frank Bachmann.*

Right Method of Paying for Water for Fire Protection. C. M. Saville. Eng. News-Record, 90: 872–4, 1923. Three ways for meeting payment for fire protection service are: (1) Unit charge per hydrant; (2) Unit charge per capita; and (3) Composite charge, consisting of unit charge per hydrant for maintenance and depreciation, plus another unit charge for pipe capacity and other costs of excess service per linear foot of pipe in service. Third method is most approved by Utility commissions. Municipal, as well as private, waterworks should get cost of service from taxpayers.—*Frank Bachmann.*

Water Filtration Plant for Omaha Metropolitan District. F. P. Larmon. Eng. News-Record, 90: 870–1, 1923. Present plant, built in 1881 consisted of sedimentation of Missouri River water through 7 basins. Inadequate on account of increasing consumption. New plant under construction will have capacity of 50 m.g.d. General engineering description of various units are detailed.—*Frank Bachmann.* (*Courtesy Chem. Abst.*)

Building Additional Siphons of Catskill Aqueduct. THADDEUS MERRIMAN. Eng. News-Record, **90**: 866–9, 1923. Original single line of concrete-covered and mortar-lined riveted steel siphons being paralleled with 2 more lines to give 500 m.g.d. capacity.—*Frank Bachmann.*

Detroit 320- M. G. D. Filtration Plant is World's Largest. T. A. LEISEN. Eng. News-Record, **90**: 860–5, 1923. Plant under construction occupies over 17 acres and comprises:—low-lift pumping station; coagulation basins; filter-beds; wash water tank; and filtered-water reservoir. Some of special features of plant include:—higher rates of filtration than usual; revolving screens for ice removal; steel roofs over filters and coagulant basin; triangular spacing of columns in filtered-water basin; and rapid mixing at high velocities. Total cost of plant is approximately $4,480,000.—*Frank Bachmann.* (*Courtesy Chem. Abst*).

Designing Filtration Plants Graphically. P. B. STREANDER. Eng. News-Record, **90**: 882–3, 1923. Charts of nomographic type shown, which simplify design of certain units such as wash trough capacities; loss of head at entry, bends, and valves; centrifugal pump capacities, efficiencies, and required power.—*Frank Bachmann.*

Overhauling Outgrown Water-Works at Fort Smith, Ark. WYNKOOP KIERSTED, JR. Eng. News-Record, **90**: 878–9, 1923. Overtaxed water-works plant at Fort Smith Ark., is receiving extensions, including 4 new filters, boilers, pumps, dry chem. feeders, and overhauling of old pumps. Supply is taken from Poteau River with turbidities of 600 to 2000 p.p.m. Extensions cost $177,000.—*Frank Bachmann.* (*Courtesy Chem. Abst.*)

Railway Water Treatment Plants and Their Operation. F. D. YEATON. Eng. News-Record, **90**: 877, 1923. Close control of operation of treatment plants is essential. Failures are traced to loose and careless control. Successful results depend on proportioning of chemicals to suit character of water and its frequent changes.—*Frank Bachmann.* (*Courtesy Chem. Abst.*)

Aeration Experiments for Removal of Carbonic Acid. WELLINGTON DONALDSON. Eng. News-Record, **90**: 874–6, 1923. Water supply of Memphis, Tenn., is taken from wells. Water contains 110 p.p.m. CO_2 of which 75 to 80 per cent is removed in pumping with air-lift pumps. It was desired to reduce CO_2 to 10 p.p.m., or less, by aeration. After carrying on extensive experiments with various types of aerating devices, multiple-tray coke scrubber type of aerator was adopted for 18 m.g.d. purification plant under construction. There will be 40 tray units, each about 2 x 7 feet in plan made up of 4 superimposed trays of coke 10 inches deep, spaced 9 inches vertically.—*Frank Bachmann.* (*Courtesy Chem Abst.*)

Sanitation of Water Supplies Main Topic of (State Sanitary Engineers) Conference. ANON. Eng. News-Record, **90**: 928–9, 1923. Revision of Treasury water standard was endorsed by conference fixing 10 cc. as the "standard

portion" and 5 such portions as the "standard sample." Not more than 10 per cent of all 10 cc. portions examined should show B. coli. Total count is omitted as index; relying solely upon B. coli. Discussion indicated need for improved and inexpensive container for shipping samples. Water containing 50 p.p.m. turbidity is suggested limit of chlorination without other treatment. *—Frank Bachmann.* (*Courtesy Chem. Abst.*)

Phenol Contamination of Public Water Supplies. CONFERENCE U. S. PUBLIC HEALTH SERVICE. Eng. News-Record, **90**: 928, 1923. Contamination of water supplies in New York, Pennsylvania, West Virginia, Ohio, Indiana, and Illinois by phenol from by-product coke ovens, gas and tar products work, is increasing and must be controlled. Chlorination of waters containing phenol *causes* offensive taste and, in one case in Ohio, chlorination was abandoned because of taste, with loss of protection to health. Two preventive methods have been considered: first, elimination of the wastes from public water supplies; and second, attempts to remove the phenol from these wastes. Latter has been successful at some plants by using wastes in coke-quenching pits. Objections to this method are odors around coke plant and decolorization of coke. Legal action is doubtful as regards results until damage to health is proven.*—Frank Bachmann.* (*Courtesy Chem. Abst.*)

Uncontrolled Pollution of Bogota Water Supply. G. C. BUNKER. Eng. News Record, **90**: 921, 1923. High water borne typhoid and dysentery rates in Bogota, Colombia, are caused by primitive insanitary conditions on watershed. Source of supply is 5 small streams, subjected to human and animal pollution. Four of streams are now chlorinated.*—Frank Bachmann.* (*Courtesy Chem. Abst.*)

Public Water Supplies in Pennsylvania. PENNSYLVANIA DEPARTMENT OF HEALTH. Eng. News-Record, **90**: 1002, 1923. Of 650 public waterworks in Pennsylvania 410 had either filtration or chlorinating apparatus in 1992. Only 7 per cent of the urban population is supplied with untreated water; 70 per cent, with filtered; and 23 per cent, with chlorination only.*—Frank Bachmann.* (*Courtesy Chem. Abst.*)

Cost of Financing in Valuation and Accounting. MAURICE R. SCHARFF. Pennsylvania W. W. Ass'n., 1922 Report. Page 28. In the Ohio Valley Water Company rate case, the Superior Court of Pennsylvania said, "If it is necessary to give a reasonable discount on bonds, such discount should be allowed as a capital charge." In the same case, the Supreme Court of Pennsylvania said, "Brokerage is a principal expense." In the Beaver Valley Water Company rate case, the Superior Court of Pennsylvania said, "Allowance should have been made for these expenses (brokerage fees) in figuring the reproduction cost." In the same case, the Supreme Court of Pennsylvania said, "The Superior Court decided otherwise (in the affirmative) and that ends the matter so far as we are concerned." Reasonable allowance must be made for cost of financing in valuation. Cost of financing in original cost should be shown correctly by the accounts and records of a Company and testimony

presented to show what such costs would be in any reproduction program.—*E. E. Bankson.*

Water Supply Contamination by Mine Drainage. J. W. LEDOUX. Pennsylvania W. W. Ass'n., 1922 Report. Page 50. Deals with law and equity regarding pollution of public water supplies by mine drainage, with special reference to the case known as "Mountain Water Supply Company vs. Melcroft Coal Company." Dealing also with processes for neutralizing mine drainage.—*E. E. Bankson.*

Maintenance and Depreciation. J. C. ADAMS. Pennsylvania W. W. Ass'n., 1922 Report. Page 76. Differentiate between proper charges to maintenance and to depreciation reserved, with definition of a "Unit."—*E. E. Bankson.*

Purification of Chester Water Supply with Special Reference to the Pollution of the Delaware River. ISAAC S. WALKER. Pennsylvania W. W. Ass'n., 1922 Report. Page 95. Due to the great quantities of sewage and wastes discharged into the River, it has been necessary to give considerable study to the pollution of the Delaware River, in order to ascertain to what extent it constitutes a menace to the water supply. From a psychological standpoint, it will be far more satisfactory to water consumers to understand that the sewage and other nauseating messes which they see floating into the streams from which their water supply is taken, are first subject to some form of treatment.—*E. E. Bankson.*

Decisions of the Court and Public Service Commissions During the Year, Affecting Water Companies. C. LARUE MUNSON AND EDGAR MUNSON. Pennsylvania W. W. Ass'n., 1922 Report. Page 131. Pointing out the salient features of each decision.—*E. E. Bankson.*

Different Sources of Electrolysis and Means of Mitigating. D. E. DAVIS AND J. P. STOW. Pennsylvania W. W. Ass'n., 1922 Report. Page 209. This electrolytic action is caused by the flow of current from the pipe system into the earth. It is at such points as the current leaves or jumps off the pipe that the pitting takes place. The amount of moisture exercises great influence in determining the ease with which the current can flow. The Bureau of Standards has recently developed an ingenious instrument which measures the intensity of current discharged, with an accuracy which was not possible heretofore. The water works operator should look with suspicion on any scheme which incorporates the use of his pipe lines for return current. Insistence should be made that the stray currents be harnessed and controlled. The most effective method in reducing electrolysis from trolley lines has been found to be the limiting of potential drop along the rails by removing the current at certain points and returning it to the power plant through insulated conductors. *Discussion by Mr. Chester.* There are very few communities in which there are not several concerns which may cause electrolysis. The practice of grounding either electric light or telephone wires through the water pipes is detrimental to the pipes. I know of no instance where alternating current has produced electrolysis.—*E. E. Bankson.*

Financing and Refinancing of Water Companies. FARLEY GANNETT. Pennsylvania W. W. Ass'n., 1922 Report. Page 225. Good service, as well as dividends, depends on good financing (personal experience related). It is always advisable to make the authorized bond issue under the mortgage large enough to cover many years growth. The depreciation reserve can be borrowed and used for extensions. Do not sell bonds or stock if you have any cash in your depreciation reserve unused. There is nothing which will tend to create a better feeling among the consumers than the distribution through the sale of preferred stock among them, or of bonds.—*E. E. Bankson.*

The Psychology of Public Utility Service. GEORGE M. HAYS. Pennsylvania W. W. Ass'n., 1922 Report. Page 247. (Personal experiences related.) The whole proposition is a mutual one, it is a partnership transaction, and unless all parties in the partnership do their share, failure will surely follow.—*E. E. Bankson.*

Rates for Private Fire Protection. W. H. ROTH. Pennsylvania W. W. Ass'n. 1922 Report. Page 285. All service lines, no matter for what purpose used, should be metered. All meters should be of the close registering type, so waste and leakage will be paid for. Water companies should not sell private fire protection service as such, but should sell water only, to be used for any purpose the customer desires. Industrial consumers should have the privilege of using as many service lines as they wish, and to select the size meter or meters they desire. For every meter used, a uniform Service Charge should be paid, no matter what the water passing through the meter is used for. All water passing through the meter should be charged for regardless as to whether it is used for general purposes or extinguishing fires. Note: Operators should absolutely refuse to install any meter that does not register all the water that passes through it.—*E. E. Bankson.*

Tendencies in Recent Decisions. JOSEPH A. BECK. Pennsylvania W. W. Ass'n., 1922 Report. Page 296. Justice Brandeis has given material support to the illogical deduction of depreciation and that the "prudent investment" shall be the controlling valuation. It is but another attempt to avoid valuation on the basis of the reproduction cost at present prices of structures, less depreciation, plus the present market value of land. Justice Brandeis said, "The occasion for the suit was solely the extraordinary rise in prices incident to the war." The court admits that these advances are to be considered in fixing a rate base. These cases (3) present rather vividly what the situation might be if we should have any "Home Rule," as it is called. These decisions make it clear that the Supreme Court has not departed from the present value principle, and that it remains the law of the land. Going value was allowed as "the cost of establishing the business as a *physically going* concern," in contrast to "the cost of developing the system into a *financially successful* concern." A utility cannot erect out of past deficits a legal basis for holding confiscatory for the future rates. "Good-will and earning power due to effective organization" are often even more important elements than tangible property, so that benefit may be had from efficient operation. Commissions

that do not allow income taxes as a part of operating expenses are in error.—*E. E. Bankson.*

Discussion on Geology of the Catskill Water Supply. WILLIAM W. BRUSH. Proc. A. S. C. E., 49: 1, 123., January, 1923. The lesson to be drawn from the work on the Catskill Aqueduct System is that coördination of geological and engineering investigations should be utilized more frequently than has been the practice. As a result of the work of the geologist, virtually no unnecessary borings were made. *Discussion by C. P. Berkey and J. P. Sanborn.* Proc. A. S. C. E., 49 3, 572, March, 1923. The geologist, therefore, should not be regarded as a substitute for exploration or an excuse for loose methods, but an interpreter of geological conditions, an aid in successful investigation, and a critical adviser in the matter of design, methods, and contracts that have to do with construction in the ground.—*E. E. Bankson.*

Water Chlorination Apparatus and its Control. G. A. H. BURN AND A. E. BERRY. Prov. Bd. of Health, Ont., Contract Record, 37: 195–9, 1923; Can. Eng., 44: 298–302, 1923. Liquid chlorine machines and their operation are minutely described particular attention being given to the compensator, gas measuring devices and mixing and feeding equipment. Wallace and Tiernan machines only are considered as this is the usual make employed and a description of the new pedestal or vacuum type is included. The Prov. Board of Health requirement for the treatment of all doubtful supplies where chlorine alone is used is that there shall be maintained a residual chlorine content of not more than 0.3 and not less than 0.2 p.p.m. after 15 minutes contact. The technique of the O-tolidin test for free chlorine is described. Eighty per cent of all water supplied for domestic consumption by municipalities in Ontario is now chlorinated —*R. E. Thompson.* (*Courtesy Chem. Absts.*)

Theory of Adsorption Processes. E. EUCKEN. Z. Elektrochem., 28: 6–16, 1922. From Chem. Absts., 16: 1525, May 20, 1922. Theoretical study and mathematical analysis of adsorption phenomena and adsorption curves, with a method of ascertaining, by direct means, the action between different molecules.—*R. E. Thompson.*

Rate of Solution of Iron in Dilute Sulfuric Acid Both when Stationary and Under Rotation. J. A. N. FRIEND AND J. H. DENNETT. J. Chem. Soc., 121: 41–4, 1922. From Chem. Abst. 16: 1527, May 20, 1922. An investigation of the rate of solution of pure and cast iron in sulfuric acid of different concentrations and temperatures. Rate of solution under rotation is directly proportional to velocity of rotation and is independent of acid concentration, indicating a different process from the corrosion of the metal in aerated water (cf. C. A. 15:3012). The presence of protective colloids, such as gum acacia, in dilute concentrations greatly retards the rate of solution of the metal both in sulfuric and hydrochloric acids.—*R. E. Thompson.*

The Hydrogen-ion Concentration of the Aqueous Solution of an Amphoteric Oxide. W. H. VAN DE SANDE BAKHUYZEN. Chem. Weekblad, 19: 41–3,

1922. From Chem. Abst., **16:** 1527, May 20, 1922. With aluminum hydroxide as an example a mathematical calculation is made to show that here too the solubility of the oxide passes through a minimum when increasing quantities of acid or base are added to an amphoteric oxide in water.—*R. E. Thompson.*

A Sensitive Test for Phenols. James Moir. J. S. African Chem. Inst., **5:** 8–9, 1922. From Chem. Abst., **16:** 1551, May 20, 1922. A test for phenols, using p-nitroaniline base, which will detect 1 p.p.m. is described.—*R. E. Thompson.*

Electroösmosis. P. H. Prausnitz. Z. Elektrochem., **28:** 27–36, 1922. From Chem. Absts., **16:** 1531, May 20, 1922. A survey of experiments indicating technical applications of electroösmosis and related processes. The importance of the further development of electrochemistry of colloids is discussed.—*R. E. Thompson.*

The Scattering of Light by Dust Free Liquids. II. W. H. Martin and S. Lehrman. J. Phys. Chem., **26:** 75–88, 1922; cf. C. A. **14:** 2878. From Chem. Absts., **16:** 1538, May 20, 1922. Measurements of the ratio of the intensity of incident light to that of scattered light show that water in the liquid state scatters about $\frac{1}{10}$ as much light as the same weight in gaseous state.—*R. E. Thompson.*

The Determination of Calcium and Magnesium in Different Saline Media. E. Canals. Bull. soc. chim., **31:** 186–92, 1922. From Chem. Abst., **16:** 1543, May 20, 1922. The determination of calcium as oxalate and of magnesium as magnesium ammonium phosphate is described. The presence of potassium sulfate, sodium sulfate and sodium chloride does not materially affect the accuracy of the determination of magnesium as pyrophosphate.—*R. E. Thompson.*

Phenol Synthesis by Bacteria. Fritz Sieke. Z. Hyg. Infektionskrankh., **94:** 214–23, 1921. From Chem. Abst. **16:** 1600, May 20, 1922. Phenol-producing bacteria, mainly of the B. coli group, were found to be present in the feces of 85 per cent of a group of people whose ages ranged from 4 days to 70 years.—*R. E. Thompson.*

The Influence of the H-Ion Concentration on the Permeability of Dead Membranes, on Absorption in Protein Sols and on Material Transport of Cells and Tissues. A. Bethe. Biochem. Z., **127:** 18–33, 1922. From Chem. Abst., **16:** 1594, May 20, 1922. The diffusion of dyes against water through parchment is very markedly influenced by the pH, diffusion of acid dyes being accelerated in acid media and retarded in alkaline solutions. An acid dye in acid solution diffuses strongly through parchment into a protein solution (gelatin) but in alkaline solution negative absorption is exhibited. The phenomena for basic dyes are the reverse to the above.—*R. E. Thompson.*

The Origin of the Electrical Charges of Colloidal Particles and Living Tissues. Jacques Loeb. J. Gen. Physiol., **4:** 351–71, 1922. From Chem. Abst., **16:**

1597, May 20, 1922. Experiments are described which prove the electric charge of suspended protein particles to be determined by the Donnan equilibrium.—*R. E. Thompson.*

An Investigation of American Stains. Report of Committee on Bacteriological Technique of the Society of American Bacteriologists. H. J. Conn. J. Bact., **7**: 127–48, 1922. From Chem. Abst. **16**: 1602, May 20, 1922. Basic fuchsin, gentian violet and methylene blue have been investigated. The present work indicates that the products of Coleman and Bell, The Chalco Chemical Co., The Providence Chemical Laboratories and the H. S. Laboratories all rank well —*R. E. Thompson.*

Determination of the Quantity of Gas and Liquid Flowing in Tubes from the Fall in Pressure. Max. Jakob. Z. Ver. deut. Ing., **66**: 178–82. 1922. From Chem. Absts., **16**: 1626, May 20, 1922. Formulas are developed for determining the quantity of gas or liquid flowing through smooth tubes. The method may be used to calibrate nozzles with an error of only a few parts per thousand. —*R. E. Thompson.*

Report of Heat Insulators. Anon. H. M. Stationery Office, Kingsway, London, W. C., Special Rept. No. 5, 1922; Analyst **47**: 119–22. From Chem. Abst., **16**: 1627, May 20, 1922. Data obtained indicate practically the same thermal conductivity for cork, slag wool, charcoal and wood fibres when of good quality and dry (0.00011 g. cal. per sec. per $cm.^2$ per $cm.^1$). Rubber expanded by gas into a highly cellular state has a conductivity of 0.000085 which is lower than that of cork and only 1.5 times that of still air.—*R. E. Thompson.*

Milk Samples Used in Determining the Purity of Water. Harald Huss. Teknisk Tids. Uppl. A., **52**: 87–9, 1922. From Chem. Abst., **16**: 1627, May 20, 1922. Water is added to samples of milk which after incubation are examined for presence of bacteria.—*R. E. Thompson.*

Oiliness or Lubricating Properties of the Various Series of Hydrocarbons. W. F. Seyer. Trans. Roy. Soc. Can., **15**: sect. III, 69–71, 1921. From Chem. Abst., **16**: 1627, May 20, 1922. The coefficient of friction of an unsaturated oil is nearly twice that of a saturated oil with the same viscosity.—*R. E. Thompson.*

Corrosion of Boilers and the Treatment of Boiler-Feed Water. A. Winstanley. Water and Water Eng., **24**: 47–9, 1922; Colliery Guardian, 223, 216. Chem. Abst., **16**: 1628, May 20, 1922. External corrosion is largely caused by sulfur dioxide in the combustion gases. General thinning is caused by free acids in the water. Grooving often occurs when boilers are frequently cooled, the action being mechanical rather than chemical. Pitting may occur even when the feed water has been softened by lime-soda. Sulfur and sulfates may be responsible for pitting as a water, which was known to be corrosive, after treatment with baryta for removal of sulfates showed no signs of corrosive power when tested in a boiler for 42 days. Corrosion by galvanic action may

be prevented by the introduction of another metallic mass which is electropositive to the boiler metal when externally connected. It is suggested that tests be made to determine whether sodium carbonate produces a brittling effect on boilers.—*R. E. Thompson.*

The Application of Ozone (to the Treatment of Water). SAMUEL BRUERE. Chimie and Industrie, 7: 30–3, 1922. From Chem. Abst., 16: 1628, May 20, 1922. The treatment of water with ozone is discussed and the equipment required is outlined. Perfect sterilization is obtained with excess ozone. The excess may be verified by passing a small stream of the treated water through a glass bulb into which starch-potassium iodide is allowed to drop.—*R. E. Thompson.*

The Chemical Sterilization of Water Without Chemical Products. S. BRUERE. Rev. hyg. pol. sanit., 43: 1247, 1921; Pub. Health Eng. Absts., Mar. 25, 1922. From Chem. Abst., 16: 1628, May 20, 1922. Sterilization of water with ozone is favored as it not only destroys the bacteria but also the toxins and does not give rise to tastes and odors.—*R. E. Thompson.*

Eleventh Annual Report of N. Y. State Conservation Commission, 1921. ANON. Pub. Health Eng. Abst., Apr. 1, 1922. From Chem. Abst., 16: 1630, May 20, 1923. Report of a conference held in Washington June 16, 1921, to consider measures for the prevention of pollution and other conservation measures relating to fisheries. A section includes a description and a series of plates showing living indicators of intensity of stream pollution.—*R. E. Thompson.*

Nitrification and Denitrification in Tropical Soils. F. C. GERRETSEN. Arch. Suikerind., 29: 1397-530, 1921. From Chem. Abst., 16: 1631, May 20, 1922. Nitrite formation in soils is largely regulated by H-ion concentration and is possible only within the limits of pH 3.9-7.2. The buffer effect of certain soil constituents, such as calcium carbonate and ferric hydroxide is important in nitrification.—*R. E. Thompson.*

Time of Set of Concrete. W. DAVIS, ET AL. Proc. Am. Soc. Testing Materials, 21: 995–1007, 1921. From Chem. Abst., 16: 1644, May 20, 1922. A method of determining the time of set of concrete, based on the time at which the concrete ceases to flow is described and it is pointed out that concrete differs from neat cement in this particular.—*R. E. Thompson.*

A Comparison of the Results of the Slump Test and the Flow Table in the Measurement of the Consistency of Concrete. W. L. SCHWALBE, ET AL. Proc. Am. Soc. Testing Materials, 21: 983–94, 1921. From Chem. Abst., 16: 1645, May 20, 1922. In general, for large scale production of concrete under approximate field and laboratory conditions, the flow table was found to be the more satisfactory method for measuring the consistency.—*R. E. Thompson.*

Determination of the Composition of Lubricating Greases. J. MARCUSSON AND H. SMELKUS. Petroleum Z., 17: 818-9, 1921. From Chem. Abst., 16:

1662, May 20, 1922. The analysis of lubricating grease is outlined. Since the war the following substitutes have been found in lubricating greases: Magnesium chloride, magnesium hydroxide, calcium chloride, calcium sulfate, sodium chloride and a yellow organic dyestuff giving the reactions of metanil yellow.—*E. R. Thompson.*

Water Purification for Textile Purposes. ROBERT S. WESTON. Am. Dyestuff Rep., **10**: 194–6, 1922; cf. C. A., **16**: 772. From Chem. Abst., **16**: 1670, May 20, 1922. The points considered were color, turbidity, mineral matter, hardness, iron and manganese. Standard methods of analysis and purification are described. Clear soft water is necessary for nearly all bleaching and dyeing operations. While mordant color may be aided by water containing iron, the amount of iron is too variable to obtain uniform results.—*R. E. Thompson.*

De-aerating of Feed water for Steam Plants. W. S. ELLIOTT. EP. P. 192, 979, May 29, 1922. Jour. Soc. Chem. Ind., **42**: 327A, April 20, 1923.—*A. M. Buswell.*

Determination of Temporary Hardness in Water. W. R. ATKIN AND A. GARDNER. J. Soc. Leather Trades Chem., **7**: 87–90, 1923, Jour. Soc. Chem. Ind.; **42**: May 4, 1923, p. 372 A. One hundred cubic-centimeters of the water is titrated cold with N/10 hydrochloric acid, using tetrabromophenolsulphonephthalein (Bromophenol Blue) as indicator. Its colour change is most marked at pH 3.8. A blank determination should be made with 100 cc. of distilled water, and any necessary correction made. If methyl orange is used as indicator the titration must be stopped when an orange shade is reached, or the colour may be compared with that obtained with an acetic acid-sodium acetate buffer mixture of pH 3.8.—*A. M. Buswell.*

Solvent Action of Oxygen-Free Fresh Water on Iron in Pipe Systems. J. TILLMANS AND B. KLARMANN. Z. Angew. Chem., **36**: 94–97, 103–1–4, 111–112, 113–115, 1923. Jour. Soc. Chem. Ind., **42**: May 4, 1923, p. 373 A. The carbonic acid contained in water may be either in a form in which it will react with calcium carbonate or in a non-"aggressive" state, but, even in the absence of the former, interaction between the latter and iron may occur. In this case, the equilibrium between bicarbonate and free carbonic acid will be upset and calcium carbonate will be deposited in the pipe at the point of action. If no "aggressive" carbonic acid is present the deposit of carbonate will protect the pipe against further action, but if it is present this will not be the case and corrosion will proceed. A theoretical study of the statics of the process shows that, with feebly acid water, electromotive equilibrium will obtain if the metal is in contact with solutions containing 15.4 moles, Fe''-ions and $10^{-6.2}$ moles, H-ions or $10^{-4.75}$ Fe''-ions and $10^{-9.8}$ H-ions per litre. With neutral water the conditions are similar, but the end-point of the reaction, is also influenced by the value of the solubility product of ferrous hydroxide. The kinetics of the reaction are conditioned by the time, nature and quantity of acid, nature and surface area of metal, temperature, and foreign matter. Starting from

the assumption that the velocity of solution of iron in carbonic acid is, at any moment, a linear function of the H-ion concentration and of the area of contact between iron and water, equations are deduced for the reaction velocity and a logarithmic function obtained for "K." Concordant results were obtained practically for "K" but its value was found to vary with the quality of iron used. The use of the formulae for determining when a water is corrosive and when not, as well as the means for improving a corrosive water, are discussed. Drinking water which is non-corrosive towards iron does not exist. In pure water the H-ion concentration is sufficient to cause dissolution, and this only ceases when the above concentration is as low as about 1×10^{-10}. Such water has a strongly alkaline reaction and taste and is unfit for drinking. For practical purposes, however, the process must be regarded kinetically. If corrosion proceeds so slowly that the water, in its passage through the pipes, has only time to dissolve an inappreciable amount of iron the water may be regarded in practice as non-corrosive. At the same time, if the water is rapidly circulated (as in cooling systems), the absence of traceable iron in it clearly does not prove that no corrosion of the pipes is taking place. Not until the water contains more than 100 mg. of fixed carbonic acid is the velocity of corrosion such as to be practically detrimental. An application of this is seen in the de-acidification of soft water by passing it over marble, though this method is not so valuable for very soft waters containing practically no bicarbonate. Water in narrow pipes contains a higher proportion of iron than that in wide pipes owing to the fact that, though in the latter a greater total amount of iron is dissolved, yet it is here distributed through a very much greater volume of water. The solubility product of amorphous ferrous carbonate was found to be 2.7×10^{-10} at 18°C., but this compound tends to form highly supersaturated solutions and so is only precipitated at much higher concentrations. The experimental check on the formulae deduced for "K" consisted in leaving iron piano wire in contact with water containing carbonic acid, but free from oxygen, in bottles which were completely filled with liquid and closed by a long capillary through which the hydrogen evolved escaped. The iron and carbon dioxide concentrations were determined. The iron solutions employed remained clear for 8–14 days and the iron itself retained its lustre or became, at worst, slightly darkened.—*A. M. Buswell.*

Discussion of Microörganisms and their Relation to Industry and Research. Symposium. Journal of Chemical Industry, **42**: *p. 169 T*, May, 1923. Abstract of discussions at a joint meeting of the London Section of Bio-chemical Society, held on January 8, 1923. *Discussions by:* A. Chaston Chapman (presiding), Sir William Pope, Prof. F. Gowland Hopkins, Prof. A. Harden, Sir John Russell, Prof. H. E. Armstrong, Prof. G. Barger, Dr. R. H. Pickard, Dr. A. C. Thaysen, Mr. E. R. Bolton, Dr. R. R. Armstrong, Mr. F. R. O'Shaughnessy. The discussion covered the entire field of micro-biology and could not profitably be further condensed from the report given in the journal, which covers eleven pages. The discussion of the nitrogen cycle by Sir John Russell of the Rothamsted Experiment Station and Mr. F. R. O'Shaughnessy discussion of the micro-biology of sewage disposal are of particular interest to sanitarians and sanitary engineers. A former proposition on the part of Mr.

Chaston Chapman, recommending the formation of a National Institute for the study of problems of micro-biology with relation to industry was endorsed by Sir William Pope in the form of a motion which was seconded by Dr. P. Dvorkovitz and carried. (The reviewer is interested to note that in such a symposium the importance of the micro-biology of sewage was recognized by including a sewage specialist in the list of speakers.)—*A. M. Buswell.*

The Aeration of Water. Geo. W. Simons, Jr. Amer. City, **28**: 251–2, 1923. Mechanical replacement of odoriferous gases by oxygen stated as underlying principle of aeration, and not oxidizing action, as commonly supposed. Six different types of aerator described and localities mentioned. Photos illustrate several common types.—*W. Donaldson.*

The Electric Power-Plant and Water-Works of Ottawa, Kans. W. O. Myers. Amer. City, **28**: 235–8, 1923. Filtration plant completed in 1921, taking supply from Marais des Cygnes river above dam; comprises sed. basin, 5 mg., storage reservoir (also used as spray pond for electric plant), 3 filter units of combined capacity 2.25 m.g.d.—*W. Donaldson.*

Oxyacetylene Torches for Melting Joints in Water-Mains. J. C. Michie. Amer. City, **28**: 349–50, 1923. Excerpts from paper before North Carolina section of A. W. W. A. 1922, describes successful use of torch as a routine water-works tool. Hand trucks provide portability.—*W. Donaldson.*

Operation of the High-Pressure Fire System in Baltimore. P. W. Wilkinson. Amer. City, **28**: 360–2, 1923. Description of system in use 10 years, costing about $900,000.—*W. Donaldson.*

Laying Steel Pipe Water Mains in Detroit. Anon. Amer. City, **28**: 439–40, 1923. Methods by which 55,000 ft. of 36 and 48-inch steel water mains were laid in 1922 are described.—*W. Donaldson.*

Albany, N. Y. Electrifies Water Purification Plant. Anon. Amer. City, **28**: 446–7, 1923. Original steam-driven pumping units for lifting water to sed, basins and pre-filters were replaced replaced with motor-driven equipment. 13,200 volts., 3 phase 40 cycle current is stepped to 440 volts for motors. The Albany plant now handles about 18.5 m.g.d.—*W. Donaldson.*

The Value of Water-Wastes Surveys. Symposium. Amer. City, **28**: 465–71, 1923. Boston, as result of three years' work, found 296 leaks, including 2 broken mains, accounting for 10.25 m.g.d., as against daily consumption 85.1 m.g.d. Survey cost of $68,000 considered well justified. Grand Rapids survey began 1921, cost about $10,000, disclosed no large breaks or leakage, but proved valuable in tracing dual piping system of which no record existed. Detroit survey covering 1151 miles of main, 24 inch and under, disclosed underground leakage 9.6 m.g.d., including partly open 6 inch blow-off and two breaks in 6 inch main. Test of large meters in place showed under registration 0.43 m.g.d., worth $51,000 annually. House fixture leakage amounted to 22.6

m.g.d. Survey located many defective valves. Department has established pitometer division as result of waste survey. Baltimore survey begun 1920 covering 153 miles of main, reduced consumption of 30.9 m.g.d. by 6.5 m.g.d. Half this amount found inside curb stop. Cost of survey averaged $168 per mile of main. Herkimer, N. Y., survey costing $1200 disclosed no considerable leakage, but cost considered justified by knowledge of pump performance and location defective valves and hydrants. Ogdensburg, N. Y., with daily consumption of 3.07 m.g. found 0.76 m.g. avoidable waste, including underground leakage of 0.35 m.g. due to two joint leaks, one cracked main, and 23 service leaks. Elmira, N. Y., found survey profitable although leakage not stated. Oswego, N. Y., survey accounted for 1.0 m.g.d. lost through unmetered fire lines due to leakage. Richmond, Ind., survey disclosed underground leakage, 0.268 m.g.d., and house wastage of 0.366 m.g.d. Water saved was estimated to pay for survey in one year's time.—*W. Donaldson.*

Milwaukee's New Meter-Repair Shop. Frank J. Murphy. Amer. City, 28: 473-6, 1923. New meter shop costing $76,000 contains many novel features. —*W. Donaldson.*

The Cost of Furnishing Water for City Uses. Anon. Amer. City, 28: 501, 1923. Tabulation from 1922 report of Springfield, Mass., shows estimated quality and value of water for various municipal uses.—*W. Donaldson.*

The Effect of Meters on Water Waste. L. R. Howson. Amer. City, 28: 547-51, 1923. Abstract from paper before Indiana Sanitary and Water Supply Ass'n. contains discussion based on survey of Chicago Water Works, where only 10 per cent services metered. Advocates universal metering and cites experiences of other cities.—*W. Donaldson.*

Quick Work in Extending a Water-Works Intake. V. Flindt. Amer. City, 28: 585-6, 1923. Describes placing of 504 ft. of 12 inch universal cast-iron pipe intake in 5-8 feet of water in Storm Lake, Iowa, by lowering through trench cut in ice.—*W. Donaldson.*

The Power Plant of the Fond du Lac, Wis., Water-Works. J. J. Breister. Amer. City, 28: 591-2, 1923. Equipment includes steam-driven pumps and air compressors, and Diesel-driven compressors for the well supply.—*W. Donaldson.*

Small Water-Works Plant in Virginia. J. N. Ambler. Amer. City, 28: 596-8, 1923. Describes completed works at Ashland, of 0.36 m.g.d. present capacity, comprising pump station, coag. basin, 2 filters, clear basin, and elevated storage tank.—*W. Donaldson.*

Developing a Park from Water-Works Earnings. A. J. Sproles. Amer. City, 28: 603-4, 1923. Proposed recreation park at Greenwood, S. C., to be financed from surplus earnings at cost of $50,000.—*W. Donaldson.*

The Determination of the Reaction of Culture Media (pH) by the Colorimetric Method. G. Abt. Revue d'Hygiène, 45: 1–43, January 1923. A general elementary paper, with bibliography of 41 titles.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*)

Bile Media for the Detection of the Colon Bacillus in Water. "D. R." and "Et R." Rev. d'Hygiéne, 45: 60–61, 1923. Formulae are given for lactose peptone bile, glucose bile (Grysez and Peret media) and the MacConkey sodium taurocholate neutral red lactose peptone medium. The bile media are recommended on account of the ease with which they may be employed.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*)

Circulation of Water through the Chalk. F. Dienert. Compt. Rendus, February 12, 1923; Water and Water Eng., 25: 115, March 20, 1923. In a catchment area, there is some fixed relation between the sinuous deepening of large valleys and the principal direction of underground water flow toward springs, though there may not be perfect parallelism between the windings of the valley and the diaclases, as phenomenon of catchment is observed when valleys and underground formations do not follow the same courses.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*)

Formation of Springs. F. Dienert. Compt. Rend., pp. 125, January 8, 1923. Water and Water Eng., 25: 115, March 20, 1923. Springs are of 2 types: those emerging from lowest points in a depression; those resulting from a re-cutting of diaclases in a more or less deep valley. As the diaclases enlarge, yield of spring water will increase by replenishing given by such enlargements; but, when reserve water is finished, yield will diminish and spring may dry up.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*)

The Fountain of Youth (Silver Spring, Florida.) Ed. Imbeaux. L'Eau, 16: 16, February 23, 1923. Comparison of Silver Spring with large French springs. Silver Spring has a delivery of 22 to 25 m^3 per second at a temperature of 21°C. Photograph and geological section.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*)

The Decomposition of Javel Water un the Colonies. Ferré. Annales de Med. et de Pharm. Coloniales, 20: 185, 1922. *Bull. Mens. Internat. Office d'Hyg. Publ.*, 15: 267, 1923. Ninety-one of 500 bottles of Javel water burst en route to Ivory Coast and others burst on storage. Author never had this experience in France. Thinks decomposition due to action of chemical rays when stored in colorless bottles.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*)

Action of Natural Waters on Lead. Part I. Saline constituents. John C. Thresh. Water and Water Eng., 25: 95, March 20, 1923. In 1921 T. showed that pure water was without action on lead, but that, in presence of O, lead oxide, or hydrate, formed, and remained in solution in colloidal condition and the water had an alkaline reaction. SO_4 has no very marked effect in retard-

ing oxidation unless in substantial quantity. With excess of CO_2 an apprecia-ble of Pb is in solution and oxidation is little, if any, retarded. NH_4NO_4 seems to have an accelerating effect, at least during early stage. PO_4 has a marked effect in producing liquid difficult to clarify. Citric and quinic acids prevent precipitation of $PbCO_3$. Alkaline hydroxides had little effect in reducing amount of Pb. odixized. SiO_2 and silicates have marked retarding action.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*)

Convention of Canadian Waterworks Officials at Toronto, Canada. Can. Eng., **44**: 10, March 6, 1923. Extensive discussion on papers entitled "Preparation of Water for Filtration," by F. A. Dallyn and A. V. Delaporte, and "Purification of Public Water Supplies," by N. J. Howard. Interesting data on theories of precipitation, alum dosage and residual chlorine given.—*Norman J. Howard.*

Outdoor Swimming Pool. Edmonton, Alberta. R. J. Gibb. Can. Eng. **44**: 12, March 20, 1923. Water turned once in 17½ hours and circulated day and night. Rapid sand filter used for purification followed by sterilisation with calcium hypochlorite. Bacterial count below 1000 per cubic centimeter. Excess chlorine maintained at 0.2 p.p.m.—*Norman J. Howard.*

Inundation Methods for Measurement of Sand. G. A. Smith and W. A. Slater. Can. Eng., **44**: 14, April 3, 1923. Tests indicated that, when sand is measured in water, quantity of sand per unit volume is almost constant, regardless of original water content of sand; and water filling voids in sand is also nearly constant for any given method of placing sand. Measurement of sand by inundation methods, should be of assistance in reducing variability of strength in concrete, caused by variations in quantities of sand and water in a batch. The use of constant water cement ratio for concrete, together with constant fineness modulus for mixed aggregate resulted in nearly constant strength, regardless of proportion of fine to coarse aggregate in mix.—*Norman J. Howard.*

Metal Corrosion. Report of Corrosion Research Committee of the Inst. of Metals (England). Can. Eng., **44**: 14, April 3, 1923. Corrosion described as oxidation of a substance, which may be produced by chemical reactions or electro-chemical means. Electro-chemical theory does not explain why certain depolarisers do not increase corrosion, but actually inhibit it. Conductivity of electrolytes is not directly connected with amount of corrosion. Impurities in metals assist local corrosion. Atmospheric oxygen has very little depolarising power at ordinary temperatures. Part played by colloids in corrosion is touched upon briefly. Electrolytic theory gives satisfactory account of the facts only under certain conditions, while many facts can be explained only by recognising important part played by colloids in corrosion. —*Norman J. Howard.*

Breakwater Construction Toronto Island. John Wilson. Can. Eng., **44**: 15, April 10, 1923. Rubble mound breakwater type of structure for prevention

of shore erosion is described in detail. Experiments also given on effects of frost on granite, limestone and trap rock.—*Norman J. Howard.*

Preparation of Water for Filtration. F. A. Dallyn and A. V. Delaporte. Can. Eng., **44**: 19, May 8, 1923. Precipitation re-actions of aluminum sulfate and relation of hydrogen ion concentration to alum dosage. Valuable data of treatment of colored waters of Ontario given; show optimum point of precipitation for these waters to be "pH" 5.5 and for Great Lake Waters (hard waters) in neighborhood of 6.5. Mechanical agitation of sand, does not, in writers' opinion, accelerate precipitation. Minimum of two hours sedimentation or coagulation for soft colored, and iron bearing waters, advocated. Where lime used for removal of CO_2, treatment should be at least 30 minutes before use of alum.—*Norman J. Howard.*

Factors in Construction of Water Works Intakes. R. W. Angus. Can. Eng., **44**: 20, May 15, 1923. Visible and submerged cribs discussed. Water should be screened on shore rather than at intake crib. Curves given showing effect of surges on intake pipes.—*Norman J. Howard.*

Value of Co-operation in Water Purification. Can. Eng., **44**: 20, May 15, 1923, Editorial. Importance of co-operation between engineer and works chemist. Claimed that active research laboratory work has resulted in marked economy and great advances in water purification. In many cases combined efforts of engineer and chemist needed to ensure success. Examples prechlorine treatment of water, sterilisation and softening of water supplies, control of chemical application by hydrogen ion theory, and treatment of algal growths in storage reservoirs and sedimentation basins.—*Norman J. Howard.*

Operating Costs for Standby Pumping Units. E. M. Proctor. Can. Eng., **44**: 21, May, 1923. Comparative pumping costs of units driven by gasoline, Diesel and steam engines given; together with charts showing effect of varying the speed of a centrifugal pump and summary of operating costs of 200 K. W. central station. As standby units for large plants, three plans suggested: 1. Steam driven reciprocating, or steam turbine driven centrifugal pumps. 2. Steam driven generator. 3. Crude oil engine of Diesel or semi-Diesel type. Diesel engines advocated as most serviceable and economical.—*Norman J. Howard.*

Big Increase in Water Consumption in Montreal. Anon. Can. Eng., **44**: 26, June, 1923. Average daily consumption in 1922 was 65 Mil. Imp. Gals. (municipal plant): of 130 Imp. Gals. per capita. Present plant unable to meet City requirements and plans under way to double capacity of plant. In 1922 86 per cent of City water was filtered, the remaining 14 per cent being chlorinated and mixed with filtered water. Ten miles of new mains laid in 1922.—*Norman J. Howard.*

Waterworks Pumping Station, St. Thomas, Ont. W. C. Millar. Can. Eng., **45**: No. 1, July 3, 1923. Prior to 1914, steam pump used for pumping,

and fuel cost of pumping and purifying water was 0.992¢ per 1000 gallons. In 1919 the cost had risen to 1.886¢ per 1000 gallons. Motor driven pumping plant, with gasoline engine-driven standby equipment was installed, and after one year's operation costs at plant showed decrease of $8418. Allowing for excess alum used on account of change in character of raw water, saving due to new pumping plant alone is $9500. After paying interest, sinking fund and fixed charges, clear saving of $3,455 remains.—*Norman J. Howard.*

The Stream Pollution Problem in Indiana. Fourth Annual Report, Department of Conservation, State of Indiana, Year ending September, 1922, p. 104. "Pollution index" of several water courses varies from 3.1 to 308, based upon density of population. Cooperation of manufacturers sought to abate gross pollution.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Water Supplies in Calcutta and Madras. MAJ. STEWART. Local Self-Government Gazette, 8: 11, 545, Nov., 1922. Opalescent character of water supplies due to colloidal clay from laterite deposits. Results from slow sand filters.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Quantitative Data in Stream Pollution Investigations. EARLE B. PHELPS. Municipal & County Engr., 63: 1, 22, July, 1922. Streams are divided into two classes, (1) potable and (2) nonpotable streams given over by common consent to drainage. Domestic and industrial wastes are classified as: (1) wastes that are directly injurious to the stream, and (2) wastes which tend to decompose or purify in the stream. Writer urges standardization of bio-chemical oxygen demand method for measuring effects of wastes on a stream.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Rainfall and its Measurement. SIR F. STUPART. Can. Eng., 44: 8, 261, February, 1923. Author discusses in detail the causes of rain, with particular reference to Canada.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Modernizing the Filter Plant of the Charlestown Water Department. F. B. McDOWELL. American City, 27: 2, 501, December, 1922. Detailed descriptions of construction of the rehabilitated water plant. Fourteen 1,000,000 gallon rapid sand filters replace twelve 500,000 gallon mechanical filters.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Device for Preventing Water Waste. Can. Eng., 44: 8, 264, February 20, 1923. Apparatus consists of chamber in which a rocking dipper, having a discharge through its axis, is arranged, constant water level in chamber being maintained by a ball cock. Water can only be obtained a dipper full at a time.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Low Level Pumping Station for the City of Montreal, Canada. C. J. DESBAILLETS. Can. Eng., 44: 8, 245, February 20, 1923. New electrically driven pumping station described and illustrated. Saving of $14.23 per m.g. by electrical equipment over steam.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Court Holds City Must Pay Damages for Typhoid. Bulletin California State Board of Health, **2**: 6, 1, March 24, 1923. Failure to operate chlorinator for one day resulted in between 125 and 150 cases of typhoic fever in June and July of 1920. Charging the city with neglect in failure to provide potable water, nineteen citizens who brought suit for damages against city were awarded $32,821.29 by the decision of the court.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Danger to Fisheries from Oil and Tar Pollution of Waters. J. S. Gutsall. Bureau of Fisheries Document No. **910**. Review of information available regarding extent and nature of oil and oil-like pollutions of water and effects on fish and other forms of aquatic life. Methods suggested for preventing pollution.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Some Observations on Aural Conditions Resulting from Pool and Sea Bathing. H. Marshall Taylor. Southern Medical Journal, **16**: 2, 134, February, 1923. Instances of acute infection of external ear, middle ear, mastoid and sinus following pool bathing. Discussions on question of direct infection versus mechanical action followed by infection.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Private Water Supplies. W. C. Folsom. Cincinnati Sanitary Bulletin, **6**: 10, 9, October 10, 1922. Recent survey by Department of Health showed 855 premises in the area of 76 square miles within city limits of Cincinnati depending on private water supplies. These were from cisterns, deep and shallow wells and springs.—*A. W. Blohm.* (*Courtesy I. W. M.*)

The Molluscan Fauna of the Big Vermillion River, with Special Reference to Its Modification as a Result of Pollution by Sewage and Manufacturing Wastes. Frank Collins Baker. Illinois Biological Monographs, **7**: 2, April, 1922. Sewage pollution has killed all clean water life for 14 miles below Urbana and made the stream an unfavorable environment for 20 miles. In this desert area, foul water algae, slime worms and septic protozoa were found.—*A. W. Blohm.*

Report of the Commission to Investigate the Pollution of Streams. Public Document, 73, State of Connecticut, January, 1923. Commission finds that in general the meager amount of work undertaken to obtain practical results from stream pollution prevention seems out of proportion to amounts of money expended. Formulation of comprehensive program to regulate amount of pollution to meet specific conditions will relieve present conditions —*A. W. Blohm.* (*Courtesy I. W. M.*)

Annual Report of the Department of Health, Government of Palestine, 1921. Piped water supplies existed in twelve towns but all were inadequate, incomplete and unsatisfactory. Public supplies from bored wells in town and deep wells or springs outside of populated sections. Chloride of lime used for purification of supplies.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Water Injection for Gas Engines. Railway Engineering and Maintenance, **19**: 327, 1923. Discussion of water injection into internal combustion cylinders is given by P. M. La Bach and C. R. Knowles.—*R. C. Bardwell.*

Report of Specifications for Contracting Water Service Work. Com. Rep., Amer. Ry. Engr. Assoc., **24**: Bull. 252, 1923. Outline of recommended specifications for contracting railroad water service work is given,—*R. C. Bardwell.*

An Economical Water Supply Plant. Wm. C. Rudd. Railway Engineering and Maintenance, **19**: 17, 1923. Description of new steam pumping plant installed by L. & N. R. R. at Decoursey, Kentucky, is given. Water secured from Licking River which has variable stage of 50 ft. Circular concrete dry well and piping arrangement with reference to suction lines and strainers are featured.—*R. C. Bardwell.*

Union Pacific Enlarges Water Plant for Pocatello Terminals. Anon. Railway Engineering and Maintenance, **19**: 1923. Additional 2 million gal. reservoir has been provided with electrically driven 3-stage centrifugal pump, to deliver 1750 gal. per minute against 380-ft. head. 3¼ miles of 10 inch and 12 inch pipe included in installation. Concrete reservoir is roofed with timber cover. —*R. C. Bardwell.*

Hydraulic Rams Provide Water Supply on Canadian National. L. H. Robinson. Railway Engineering and Maintenance, **19**: 239, 1923. Pumping plants at 15 main line stations are replaced by hydraulic rams at 13 stations with saving of $79,730. This method of providing water supply for railroads is recommended where practicable, due to simplicity and being "fool proof."—*R. C. Bardwell.*

Relative Merits of Cast Iron, Steel, Wood, and Other Materials, for Pipe Lines. Com. Rep., Amer. Ry. Engr. Assoc., **24**: Bul. 252, 1923. History and discussion of pipe lines to be used in Railway water service is given, together with merits of different classes of pipe for respective service. Cast iron pipe is recommended for practically all underground water service conditions and for installations where permanency and durability are desired.—*R. C. Bardwell.*

Use of Oil Engines in Railway Pumping Stations. Com. Rep., Amer. Ry. Engr. Assoc., **24**: Bul. 252, 1923. Discussion of development of use of oil engine in Railway pumping stations is given.—*R. C. Bardwell.*

Water Supply at Hoisington, Kansas, Mo. Pac. R. R. Anon. Railway Review, **72**: 959, 1923. Mo. Pac. R. R. recently completed new 200 million gallon water storage reservoir, with 6½ mile pipe line and pumping station, and 3-tank intermittent water treating plant, at Hoisington, Kansas, to obtain adequate supply and eliminate corrosive effect on locomotive boilers of ground water formerly used which contained high NaCl. Full description, with quantity details, is given.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Fuel Saving Aspect of Boiler Water Treatment. C. R. KNOWLES. Railway Age, **74**: 1288, 1923. Approximately 500 billion gallons of water used annually for steam purposes on American Railroads, of which only 13 per cent is treated. Discussion of possible economies in fuel from scale removal.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

New Features Incorporated in Water Softening Plants. C. R. KNOWLES. Railway Engineering and Maintenance, **19**: 273, 1923. New type of conical bottom steel tank for water softening plants is featured; with full description of operation and results. Chief advantage claimed is method for sludge removal.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Standard Method of Water Analysis—Interpretation and Results. Com. Rep., Amer. Ry. Engr. Assoc., **24**: Bul. 252, 1923. Progress report recommends reporting hypothetical combinations in grains per gal. and lbs. per M. gal.; in line with modification of the Fresenius method. Rapid boiler analysis based on volumetric methods entirely, with exception of total solids. A. P. H. A. method is recommended for full and complete examination.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Pitting and Corrosion of Boiler Tubes. Com. Rep., Amer. Ry. Engr. Assoc., **24**: Bul. 252, 1923. Progress report on results of study of pitting and corrosion by committee.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Progress of Regulations of Federal and State Health Authorities Pertaining to Drinking Water Supply. Com. Rep., Amer. Ry. Engr. Assoc., **24**: Bul. 252, 1923. Reference is made to progress and interpretaton of Interstate Quarantine Regulation pertaining to Railway drinking water supply.—*R. C. Bardwell* (*Courtesy Chem. Abst.*)

How the Illinois Central Handles Its Water Service. DAVID A. STEEL. Railway Maintenance and Engineering, **19**: 182, 1923. Full and complete description of water service on Illinois Central R. R. is given; including maps, illustrations, and charts showing results and typical installations. Centrifugal pumps with oil engine or electric drive are featured. Saving from water treatment exceeds $220,000 per year from removal of 2,425,900 lbs. scale from over one billion gallons water.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Value of Water Treatment to Railroad. Com. Rep., Amer. Ry. Engr. Assoc., **24**: Bul. 252, 1923. Progress report.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Time Required to Settle Muddy Water. Railway Engineering and Maintenance., **19**: 324, 1923. Question of time necessary for satisfactory sedimentation of muddy water discussed by C. R. KNOWLES, BERNARD BLUM and C. H. KOYL.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Missouri Pacific Builds Large Water Supply and Softening Plant. ANON. Railway Engineering and Maintenance, **19**: 317, 1923. Mo. Pac. R. R. has com-

pleted 200 million-gallon storage reservoir, with 6½-mile pipe line, and 3-tank intermittent type water softening plant, with double unit 4 inch centrifugal transfer pumps. Quantities, diagram and photographs are shown.—*R. C. Bardwell.* (*Courtesy Chem. Abst.*)

Putting a Small Water Works on Its Feet. J. W. Hockaday. Fire & Water Eng., **73**: 95, January 10, 1923. Some features of water works of Cleburne, Texas, which derives its water from an underground system. By inaugurating system of checking meters, it was found that many meters were dead; many did not register over 15 per cent; and only a small proportion, as high as 75 per cent. Some meters had been in service for 10 years without being checked. Only 1 gallon of water was paid for out of every 3 pumped, although city was 100 per cent metered. Overhauling of meters has produced very gratifying results.—*Geo. C. Bunker.*

Cast Iron Pipe Prices. Fire & Water Eng., **73**: 98, January 10, 1923. Table of monthly prices of 6-inch. pipe per net ton, at New York, from 1902 to 1922, inclusive.—*Geo. C. Bunker.*

Some Practical Ideas on Water Works Operation. Thomas H. Hooper. Fire & Water Eng., **73**: 101, January 10, 1923. Notes concerning some features of water works of Winnipeg, Man., Canada.—*Geo. C. Bunker.*

How to Select and Install Master Meters. Waldo S. Coulter. Fire & Water Eng., **73**: 175, January 24, 1923. Discussion of selection and installation of Venturi and proportional-flow meters, for measuring (a) pumpage at a station; (b) flow entering system from a reservoir; (c) discharge into system at one or more points on corporate limits of a municipality, or at points of delivery of supplemental supply from outside sources to any system. Measurement of water through private fire connections is also considered. Brings out many points of practical value to superintendents. Illus.—*Geo. C. Bunker.*

Making Repairs to Pipe Under Pressure. John N. Foulks. Fire & Water Eng., **73**: 179, January 24, 1923. Leak in 36-in. riveted steel pipe, under 90 lbs. pressure, through hole approximately 3/8 in. diameter, was stopped by driving in pine plug, which was cut off flush with surface of pipe and then covered by metal cap which was welded to pipe by electric arc. Many pits in same section were also filled and reinforced by welding. Cost was $0.77 per lineal foot, exclusive of cost and depreciation of gasoline driven arc welding set mounted on Ford chasis. Illus.—*Geo. C. Bunker.*

High Pressure Supply Furnished by Manchester Water Works. F. Johnstone-Taylor. Fire & Water Eng., **73**: 216. January 31, 1923. Manchester, England, in addition to its gravity water supply, furnishes a high pressure supply for operating lifts and presses in warehouse district. Electrically driven centrifugal pumps were recently installed, which deliver 800 gallons per minute at pressure of 1150 lbs. per sq. in.; motor is of 1000 B. H. P., and runs at 1475 r. p.m. Illus.—*Geo. C. Bunker.*

Installing Internal Combustion Engines. Fire & Water Eng., **73**: 262, February 7, 1923. Regulations, suggested by National Board of Fire Underwriters, for installing all types of internal combustion engines-fuel oil, gas, gasoline, and kerosene.—*Geo. C. Bunker.*

How the British Water Works Functions. F. JOHNSTONE-TAYLOR. Fire & Water Eng., **73**: 297, February 14, 1923. Outside the London Metropolitan Water Board, the Government has little to do with water supply, beyond such controlling influence as Ministry of Health exerts. This department has replaced old Local Gov't. Board, and supervises expenditure of public money and administration of affairs of Local Authorities, which may be either city corporations, urban district councils of smaller towns, or rural district councils of country districts. After a proposition has been sanctioned by Ministry of Health, Local Authority may levy a rate for meeting either cost of works, or interest on loan therefor, or both. Loans are obtainable at low rate of interest, about 5-1/2 per cent at beginning of 1923. For very large schemes, a bill may have to be promoted in Parliament which requires a long time and is very expensive. Direct labor under water works engineer is little employed on construction works. In nearly every case, tenders are invited and publicly advertised. Work generally goes to lowest bidder, if he is considered capable of completing work at price submitted. Specifications are generally rigid, and ridigly observed. Ministry of Health has power to set fair price for necessary land. A water works engineer paid by Local Authority must be elected by a majority of votes of council. In days gone by, this system obviously led to a good deal of influences being sought by incompetent men. In England, anyone can call himself a civil engineer; Institute of Civil Engineers has sought in vain for this to be made illegal. Fortunately, Ministry of Health has to sanction payment of engineer's salary. Engineers of large undertakings are highly qualified and, often, eminent men. They are well paid, 1000 Pounds a year being a good average salary. Larger percentage of water supplies in Great Britain are obtained by gravity from upland waters. In pumping stations, steam is generally employed; although gas engines are used a good deal for smaller plants, and Diesel engine is becoming popular. Softening plants are installed where necessary, and in case of upland and river supplies, slow sand filtration is generally employed; rapid sand filters are coming into general use. All the London water companies have now been absorbed by Metropolitan Water Board. This is practically a government department, and is subject to a good deal of criticism on account of very high water charges and none too generous supply. With very few exceptions, all ordinary business premises and all private dwellings within an area of supply are entitled to an unlimited quantity of water at a fixed charge per year. This charge, which is known as the "water rate," is fixed by the rateable value of the property. It varies according to cost of administration and is generally payable yearly. The average quantity of water consumed per head per day in Great Britain is 30 gallons. Factories and other premises using an abnormal quantity of water are supplied by meter. Water borne typhoid is now practically non-existent, water famines rare, failures of dams practically unknown, and poisoning, due to water, almost unheard of.—*Geo. C. Bunker.*

Delaware River Proposed as Future New York Water Supply. Fire & Water Eng. **73**: 341, February **21**, 1923. Letter from Board of Water Supply to Governor Smith, suggesting that, as Delaware River is most logical supply for greater city when it shall have outgrown Catskill and Croton Systems, he appoint a commission to confer with similar bodies from Pennsylvania and New Jersey to consider proper development of great water resources of that river.—*Geo. C. Bunker.*

A Progressive Water Works and Its Methods. Articles on various activities of the East Bay Water Co., of California. Fire & Water Eng. (1) **The Pumping System of the East Bay Water Company.** Harry Rainhardt. **73**: 375, February 28, 1923. Company is now operating 30 pumping stations, three of which are steam driven, and 27, electric driven. Daily pumpage varies from minimum of 26.8 to maximum of 41.0, with average of 33.8 million gallons. In some instances, water is pumped as many as seven times before it reaches consumers. Recent tendency of pumping department has been toward installation of automatic pumping stations where possible. Schematic diagram shows sources of supply, pump plants, storage and distribution reservoirs with elevations and capacities.—(2) **Handling Difficult Water Distribution Problems.** F. J. Klaus. **73**: 459, March 14, 1923. East Bay territory served by company is now divided into 27 pressure zones, each having separate distribution reservoirs and, in many cases, separate transmission lines. The great range in elevation within the few miles of width of service tends to make zoning frequent and causes lines of low and high pressure to fall at close intervals; with result of many complaints from consumers. Principal sources of supply are below 240-foot elevation. About one-half of gridiron lies above this height, so that large proportion of water is handled by pumps. Trend of building is toward hilltops. Pumping stations within residential sections are made as sound proof as possible and architecture is made to conform to surrounding structures. Reservoir roofs are designed to be sightly, and surrounding grounds are being parked by capable landscape engineers. Water is distributed under pressures ranging from 30 to 125 lbs. Excessive daily draft in small isolated zones is problem which has not been overcome entirely. Within last few years, mechanical pressure regulators have been used for feeding water from large reservoir in high zone to lower zone having small storage. Low side of regulators are set to open when pressure in lower zone drops below normal, due to excess draft. Regulators used have proven effective and not at all troublesome. Under changing conditions, systems are built as inexpensively and economically as possible; pipe system has little excess capacity; sheet-iron pipe is used in place of cast-iron; pressure is broken by wood tanks instead of finished reservoirs, or standpipes. This method has proven economically sound after many tests made during last 15 years. (3) **Practice of the Company in Maintaining Shops and Yards.** Harry Reinhardt and Fred J. Klaus. **73**: 579, April 4, 1923. Corporation yard of company operates under direction of engineering department, as its function is supplying of materials, making repairs, etc. A general storekeeper is actively in charge. Accounting system is carried on by auditing department, without any overlapping of authority. All ordinary repair work from pumping stations is handled in

machine shop and blacksmith shop. The garage maintains, repairs, overhauls, paints, and services all motor equipment. Meter shop attends to meter repairing and testing. Men from carpenter shop take care of all repairs of buildings. (4) **Sanitary Control over Watershed Areas.** P. I. DANIELS. **73**: 580, April 4, 1923. All surface water collected by company is derived from four watersheds with combined area of 80.05 sq. miles. Percentages of areas owned by company are 34, 47, 70, and 100. Nearly all land owned in watersheds is leased to various tenants, uses to which the land may be put being restricted to growing of hay, grain, fruit, and to cattle raising. Cattle grazing is restricted and under control of company. Neither dairies, nor hog raising, are allowed on property inside catchment areas. Watershed areas are divided into districts; each district being in charge of sanitary patrolman who lives within district. Patrolmen attend to enforcement of sanitary laws regarding public water supplies in state of California; and, in addition, are deputy state fire wardens under state board of forestry. Rain gages are installed at or near residence of each sanitary patrolman. Water obtained from catchment areas is impounded in storage reservoirs, then passed through sedimentation basins and rapid sand filters, and finally disinfected with liquid chlorine.—*Geo. C. Bunker.*

Report of the Investigations of Sanitary Conditions of the Calumet River Drainage Area. L. A. GEUPEL. Proc. Indiana Sanitary and Water Supply Association, p. 140, 1921–1922. Report discusses findings of sanitary survey of Calumet River drainage area. Pollution contributed to Lake Michigan by large volume of domestic and industrial wastes constitutes serious menace to water supplies of Indiana cities using Lake Michigan as source.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Review of East Chicago Filter Operation and Waste Reduction. E. J. JENKINS. Proc. Indiana Sanitary and Water Supply Association, p. 161, 1921–1922. Tabulated operating data of rapid sand filtration plant of East Chicago and Indiana Harbor Water Company. Per capita consumption reduced in 16 months from 234 to 71 gallons by installation of meters and campaign against waste.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Filter Underdrains of the Perforated Type. W. W. DEBERARD. Proc. Indiana Sanitary and Water Supply Association, p. 32, 1921–1922. Conclusions of H. N. Jenks on investigation of underdrain design.—*A. W. Blohm.* (*Courtesy I. W. M.*)

More About Chlorination. ANDREW BALFOUR. Trans. Royal Society of Tropical Medicine and Hygiene, **16**: 332, Nov. 5 & 6, Nov. & Dec., 1922. Review of Hodgkinson and Hutchinson method of manufacturing electrolytic chlorogen (E. C.). In this process a 20 to 25 per cent brine solution with addition of 1 per cent lime is electrolyzed. Claimed that at 20°C. E. C. solution with 2.5 per cent available chlorine remains stable for 12 months.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Ozone and Electrolytic Water Purifying Apparatus. Technical Publication, No. 10, 1923. United States Ozone Company, Scottsdale, Pennsylvania. Con-

struction and action of water ozonizers and advantages of method.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Concrete Pipe: Plain and Reinforced. Joseph S. Lambie. Proc. Engineers Society of Western Pennsylvania, 38: 10,471, January, 1923. History of design, manufacture and use of concrete pipe. Proposed changes in methods of testing.—*A. W. Blohm.* (*Courtesy I. W. M.*)

Studies on Oxidation-Reduction. I. Introduction. W. Mansfield Clark. P. H. Reports, 38: 10, March 9, 1923. Experimental data, prefaced by review of elementary principles of oxidation and reduction, and theoretical analysis of relations between electrode potentials and pH. Electron is defined as unit, negative charge. Addition of electrons results in reduction of a compound, and withdrawal of electrons results in its oxidation. Addition and withdrawal of electrons may be effected with or without the withdrawal and addition of oxygen, respectively. Author considers ratio of reductant to oxidant and the conditions under which this ratio varies. Normal hydrogen electrode is defined as a platinized platinum electrode held under one atmosphere of hydrogen and immersed in a solution normal with respect to the hydrogen ions. The arbitrary value "zero" is assigned to potential difference at this electrode. It is possible to express relative oxidation-reduction intensities in terms of electrode potential. Oxidation-reduction intensity is different from capacity of a solution to oxidize or reduce. The distinction is analogous to that between capacity and intensity factors in acidity-basicity.—*Bernard S. Coleman.*

Studies on Oxidation-Reduction, III. Electrode Potentials of Mixtures of 1-Naphthol-2-Sulphonic Acid Indophenol and the Reduction Product. W. Mansfield Clark and Barnett Cohen. P. H. Reports, 38: 18, May 4, 1923. Authors describe new indophenol, methods of synthesis, equipment, and methods of studying reduction potentials of the compound in equilibrium with its reduction product at different pH values of solution. It is suggested that the reduction of this new indophenol should indicate minute degrees of physiological reduction, for it is shown that an 80–90 per cent reduction of 1-naphthol-2-sulfonate indophenol within the ordinary range of pH, indicates a reduction potential about 0.52 volt more positive than the hypothetical electrode potential of the solution.—*Bernard S. Coleman.*

The Principles Underlying the Movement of Bacillus Coli in Ground Water, with Resulting Pollution of Wells. C. W. Stiles and Harry R. Crohurst. P. H. Reports, 38: 24, June 15, 1923. (Abstract of part of Annual, 1922–1923, Report of the Board on Excreta Disposal presented to the conference of State Health Officers, Washington, D. C., May 17, 1923.) Summarized results of experiments on movement of B. coli through fine sand. B. coli found in ground water 65 feet. from source of pollution after travelling through sand with effective size of 0.13 mm. Pollution travels in direction of flow of ground water, and at surface of saturation zone. Progressive movement and stranding of pollution vary with rise and fall of ground-water level. Results of ex-

periments have important bearing upon intermittent well pollution, location of water supplies and location of camps. Article is followed by classification of subsurface waters of the lithosphere (arranged from a manuscript of O. E. Meinzer, U. S. Geol. Survey).—*Bernard S. Coleman.*

Analyse General des Eaux. M. F. Touplain. New Book, Published by Libraire Polytechnique Ch. Beranger, 15 Rue des Saintes-Pères, 1922, pp. 244, 31 fig., Fr. 25; post free, foreign, Fr. 27.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*)

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